25-7

U.S. Department
of Transportation

Federal Aviation
Administration

# Advisory Circular

AC 25-7

DATE 4/9/86

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# FLIGHT TEST GUIDE
## FOR CERTIFICATION OF TRANSPORT CATEGORY AIRPLANES

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U.S. Department of Transportation
**Federal Aviation Administration**

# Advisory Circular

**Subject:** FLIGHT TEST GUIDE FOR CERTIFICATION OF TRANSPORT CATEGORY AIRPLANES

**Date:** 4/9/86
**Initiated by:** ANM-110
**AC No:** 25-7
**Change:**

1. PURPOSE. This advisory circular (AC) provides guidelines for the flight test evaluation of transport category airplanes. These guidelines provide an acceptable means of demonstrating compliance with the applicable airworthiness requirements. The methods and procedures described herein have evolved through many years of flight testing of transport category airplanes and, as such, represent current certification practice. Like all AC material, these guidelines are not mandatory and do not constitute regulations. They are derived from previous FAA experience in finding compliance with the airworthiness requirements and represent the methods and procedures found to be acceptable by that experience. Although mandatory terms such as "shall" or "must" are used in this AC, because the AC method of compliance is not itself mandatory, these terms apply only to applicants who seek to demonstrate compliance by use of the specific method described by this AC.

2. BACKGROUND. Order 8110.8, Engineering Flight Test Guide for Transport Category Airplanes, dated 9/26/74, was published for internal use to describe acceptable means of compliance with the flight test portions of Part 25 of the Federal Aviation Regulations. This AC, which is an update of Order 8110.8 in the areas of performance and flying qualities, covers Subpart B--Flight. This material has simultaneously been removed from Order 8110.8. As additional sections are developed, this AC and Order 8110.8 will be revised accordingly.

3. APPLICABILITY. These methods and procedures are promulgated, in the interest of standardization, for use during all transport category airplane flight test certification activities. This material is not to be construed as having any legal status and must be treated accordingly. The procedures set forth herein are one acceptable means of compliance with applicable sections of Part 25. Any alternate means proposed by the applicant should be given due consideration. Applicants are encouraged to use their technical ingenuity and resourcefulness in order to develop more efficient and less costly methods of achieving the objectives of Part 25. Since these methods and procedures are only one acceptable means of compliance, individuals should be guided by the intent of the methods provided in this AC. As deviations from the methods and procedures described in this AC may occur, FAA certification personnel will coordinate what they consider to be major deviations with the Transport Standards Staff (ANM-110) of the Transport Airplane Certification Directorate. If in their judgement, however, a deviation is considered to be minor, coordination with ANM-110 may not be necessary.

4. RELATED PUBLICATIONS. Certification personnel should be familiar with FAA Order 8110.4, "Type Certification," and FAA Order 8100.5, "Aircraft Certification Directorate Procedures." In this AC, reference is made to other FAA ACs which give guidance on various aspects of type certification and supplemental type certification.

Leroy A Keith

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Manager, Aircraft Certification Division

# CONTENTS

## Chapter 1. GENERAL

Paragraph Page No.

1. FAR 25.1 Applicability (RESERVED)
2. FAR 25.2 Special Retroactive Requirements (RESERVED)

## Chapter 2. FLIGHT

### Section 1. GENERAL

3. FAR 25.21 Proof of Compliance . . . . . . . . . . . . . . . . . . . 51
4. FAR 25.23 Load Distribution Limits (RESERVED)
5. FAR 25.25 Weight Limits (RESERVED)
FAR 25.27 Center of Gravity Limits (RESERVED)
6. FAR 25.29 Empty Weight and Corresponding Center of Gravity (RESERVED)
7. FAR 25.31 Removable Ballast (RESERVED)
8. FAR 25.33 Propeller Speed and Pitch Limits . . . . . . . . . . . 59

### Section 2. PERFORMANCE

9. FAR 25.101 General [RESERVED]
FAR 25.103 Stalling Speed (see paragraph 29)
10. FAR 25.105 Takeoff . . . . . . . . . . . . . . . . . . . . . . . . 201
FAR 25.107 Takeoff Speeds
11. FAR 25.109 Accelerate-Stop Distance . . . . . . . . . . . . . . . 207
12. FAR 25.111 Takeoff Path . . . . . . . . . . . . . . . . . . . . . 214
13. FAR 25.113 Takeoff Distance and Takeoff Run . . . . . . . . . . . 220
14. FAR 25.115 Takeoff Flight Path . . . . . . . . . . . . . . . . . . 223
15. FAR 25.117 Climb: General (RESERVED)
16. FAR 25.119 Landing Climb: All Engines Operating . . . . . . . . . 225
17. FAR 25.121 Climb: One-Engine Inoperative . . . . . . . . . . . . 226
18. FAR 25.123 Enroute Flight Paths . . . . . . . . . . . . . . . . . 227
19. FAR 25.125 Landing . . . . . . . . . . . . . . . . . . . . . . . . 228

### Section 3. CONTROLLABILITY AND MANEUVERABILITY

20. FAR 25.143 General . . . . . . . . . . . . . . . . . . . . . . . . 301
21. FAR 25.145 Longitudinal Control . . . . . . . . . . . . . . . . . 301
22. FAR 25.147 Directional and Lateral Control . . . . . . . . . . . . 305
23. FAR 25.149 Minimum Control Speed . . . . . . . . . . . . . . . . 307

### Section 4. TRIM

24. FAR 25.161 Trim (RESERVED)

Paragraph Page No.

### Section 5. STABILITY

25. FAR 25.171 General (RESERVED)
26. FAR 25.173 Static Longitudinal Stability . . . . . . . . . . . 451
FAR 25.175 Demonstration of Static Longitudinal Stability
27. FAR 25.177 Static Directional and Lateral Stability . . . . . . 453
28. FAR 25.181 Dynamic Stability . . . . . . . . . . . . . . . . . 455

### Section 6. STALLS

29. Stall Testing . . . . . . . . . . . . . . . . . . . . 501
FAR 25.201 Stall Demonstration
FAR 25.203 Stall Characteristics
FAR 25.205 Stalls: Critical Engine Inoperative
FAR 25.207 Stall Warning

### Section 7. GROUND AND WATER HANDLING CHARACTERISTICS

30. General . . . . . . . . . . . . . . . . . . . . 551
FAR 25.231 Longitudinal Stability and Control
FAR 25.233 Directional Stability and Control
FAR 25.235 Taxiing Condition (RESERVED)
FAR 25.237 Wind Velocities
FAR 25.239 Spray Characteristics, Control, and Stability on Water

### Section 8. MISCELLANEOUS FLIGHT REQUIREMENTS

31. FAR 25.251 Vibration and Buffeting . . . . . . . . . . . . . . . 601
32. FAR 25.253 High Speed Characteristics . . . . . . . . . . . . . 605
33. FAR 25.255 Out-of-Trim Characteristics . . . . . . . . . . . . 608

## Chapter 3. STRUCTURE

(RESERVED)

## Chapter 4. DESIGN AND CONSTRUCTION

(RESERVED)

## Chapter 5. POWERPLANT

(RESERVED)

## Chapter 6. EQUIPMENT

(RESERVED)

READEX FICHE best copy available

Paragraph Page No.

Chapter 7. OPERATING LIMITATIONS & INFORMATION

(RESERVED)

Chapter 8. AIRWORTHINESS--MISCELLANEOUS ITEMS

(RESERVED)

PARAGRAPH PAGE

Section [illegible]. STABILITY

[illegible]

25. FAR 25.17[illegible] [illegible]
26. FAR 25.17[illegible] [illegible] [illegible]
FAR 25.17[illegible] [illegible] of [illegible]
27. FAR 25.177 Static Directional and Lateral Stability [illegible]
28. FAR 25.[illegible] Dynamic Stability [illegible]

[illegible]

29. Stall [illegible] [illegible]
FAR 25.[illegible] Stall Demonstration
FAR 25.[illegible] Stall Characteristics
FAR 25.[illegible] [illegible] [illegible]
FAR 25.[illegible] Stall Warning

Section [illegible]. GROUND AND WATER HANDLING CHARACTERISTICS

30. General [illegible]
FAR 25.231 Longitudinal Stability and Control
FAR 25.233 Directional Stability and Control
FAR 25.235 Taxiing Condition [illegible]
FAR 25.237 Wind Velocities
FAR 25.239 Spray Characteristics, Control, and Stability on Water

Section [illegible]. MISCELLANEOUS FLIGHT REQUIREMENTS

31. FAR 25.251 Vibration and Buffeting [illegible]
32. FAR 25.253 High-Speed Characteristics [illegible]
33. FAR 25.255 Out-of-Trim Characteristics [illegible]

CHAPTER 3. STRUCTURE

[Reserved]

CHAPTER 4. DESIGN AND CONSTRUCTION

[Reserved]

CHAPTER 5. POWERPLANT

[Reserved]

CHAPTER 6. EQUIPMENT

[Reserved]

# CHAPTER 1 - GENERAL

1.-2. [RESERVED]

# CHAPTER 2 - FLIGHT

## Section 1. GENERAL

### 3. PROOF OF COMPLIANCE - § 25.21.

a. Explanation.

(1) Section 25.21(a) - Proof of Compliance (Airplane Loading Conditions).

(i) The burden of showing compliance with the flight requirements for an airworthiness certificate or a type certificate rests with the applicant. The applicant should, at his own expense and risk, conduct such official flight tests as required by the FAA to demonstrate compliance with the applicable requirements. During the type inspection, the applicant should make available the airplane, as well as all of the personnel and equipment necessary to obtain and process the required data.

(ii) If the airplane flight characteristics or the required flight data are affected by weight and/or c.g., the compliance data should be presented for the most critical weight and c.g. condition.

(iii) The gross weight and c.g. tolerances specified in paragraphs (3)(ii)(A) and (C) are test tolerances and are not intended to allow compliance to be shown at less than critical conditions.

(2) Section 25.21(c) - Proof of Compliance (Altitude Effect on Flight Characteristics).

(i) Any of the flying qualities, including controllability, stability, trim, and stall characteristics, affected by altitude should be investigated for the most adverse altitude conditions approved for operations and limited, as appropriate, in accordance with § 25.1527.

(ii) Consideration should be given in the test program for aerodynamic control system changes with altitude (e.g., control throws or auto slats which are sometimes inhibited by Mach number at altitude).

(3) Section 25.21(d) - Proof of Compliance (Flight Test Tolerances).

(i) To allow for variations from precise test values, certain tolerances during flight testing should be maintained. The purpose of these tolerances is to allow for variations in flight test values from which data are acceptable for reduction to the value desired. They are not intended for tests to be routinely scheduled at the lower weights, or to allow for compliance to be shown at less than the critical condition; nor are they to be considered as allowable inaccuracy of measurement. As an example, when demonstrating stability with a specified trim speed of $1.4V_{S1}$, the trim speed may be $1.4V_{S1} \pm 3$ knots or 3 percent; however, no positive tolerance is permitted when demonstrating the minimum prescribed trim speed $1.4V_{S1}$ (Ref. § 25.161).

(ii) Where variation in the parameter on which a tolerance is allowed will have an effect on the results of the test, the results should be corrected to the most critical value of that parameter within the operating envelope being approved. If such a correction is impossible or impractical (e.g., performance at forward c.g.), the average test conditions should assure that the measured characteristics represent the actual critical value.

(A) Weight extrapolation limits. Test data may be extrapolated to higher gross weights than specified below if the available test data includes an adequate range of weights and an appropriate number of points at the maximum test weight. If the test data analysis verifies the predicted effect of weight, then other extrapolation limits may apply. Extrapolation limits are given in Figure 3-1 below:

FIGURE 3-1. WEIGHT EXTRAPOLATION LIMITS

| Flight Test Models | Weight Extrapolation Limit | |
|---|---|---|
| | +5% | +10% |
| Stall Speeds | X | |
| Stall Characteristics | | X |
| Climb Performance | X | |
| Takeoff Flight Paths | X | |
| Landing Braking Distance | X | |
| Landing Air Distance | X | |
| Takeoff Distance & Speed | X | |
| Max KE RTO's | X | |
| $V_{MU}$ | | X |

(B) Wind Limits. For takeoff and landing tests, a wind velocity limit of 10 knots (from any direction) or $.12V_{S1}$ (whichever is lower) at the height of the MAC with the airplane on the ground has been considered the maximum acceptable. Because of likely unsteady wind conditions, it is generally considered that takeoff and landing performance data obtained under runway wind conditions greater than 5 knots are likely to be inconsistent and unreliable. If performance data are obtained with winds greater than 5 knots, these data should not necessarily be ignored.

(C) C.G. Limits. A test tolerance of ±7 percent of the total c.g. range is intended to allow some practical relief for inflight c.g.

movement. This relief is only acceptable when the test data general scatter is about the limiting c.g. or when c.g. correction from test c.g. to limit c.g. is acceptable.

(D) Airspeed Limits. Normally, tests conducted within 3 percent or 3 knots (whichever is the higher) of the desired test speed are considered acceptable.

(iii) Because the tolerance values normally are not considered in the airplane design substantiation, it is not the purpose of these tolerances to allow flights at values in excess of those authorized in the type design. If such flights are to be conducted, adequate structural substantiation for the flight conditions should be available. These flights, however, are always conducted under controlled conditions and with the flight test crew's full cognizance of the situation. Examples of such flights are:

(A) Takeoff at greater than maximum takeoff weight for the purpose of reaching a test area at the maximum takeoff weight.

(B) Landing at greater than maximum landing weights during the course of conducting takeoff tests.

(C) To obtain data for future approvals beyond that substantiated for the initial type design.

(iv) The following list indicates the cases in which corrections are normally allowed:

FIGURE 3-2. TEST PARAMETERS THAT NORMALLY CAN BE CORRECTED

| Test | Wt. | C.G. | Airspeed | Altitude | Power or Thrust | Wind |
|---|---|---|---|---|---|---|
| Airspeed calibration | X | --- | --- | --- | --- | --- |
| Stall speeds | X | X | --- | --- | X | --- |
| Climb performance | X | --- | --- | X | X | --- |
| Landing performance | X | --- | X | X | --- | X |
| Takeoff performance | X | --- | --- | X | X | X |
| Accelerate-stop perf. | X | --- | --- | X | X | X |
| Minimum control speed | --- | --- | --- | --- | X | --- |
| Minimum unstick speed | X | X | X | --- | X | --- |
| Buffet boundary | X | X | --- | X | --- | --- |

(v) All instrumentation used in the flight test program should be appropriately calibrated and acceptable to the FAA test team.

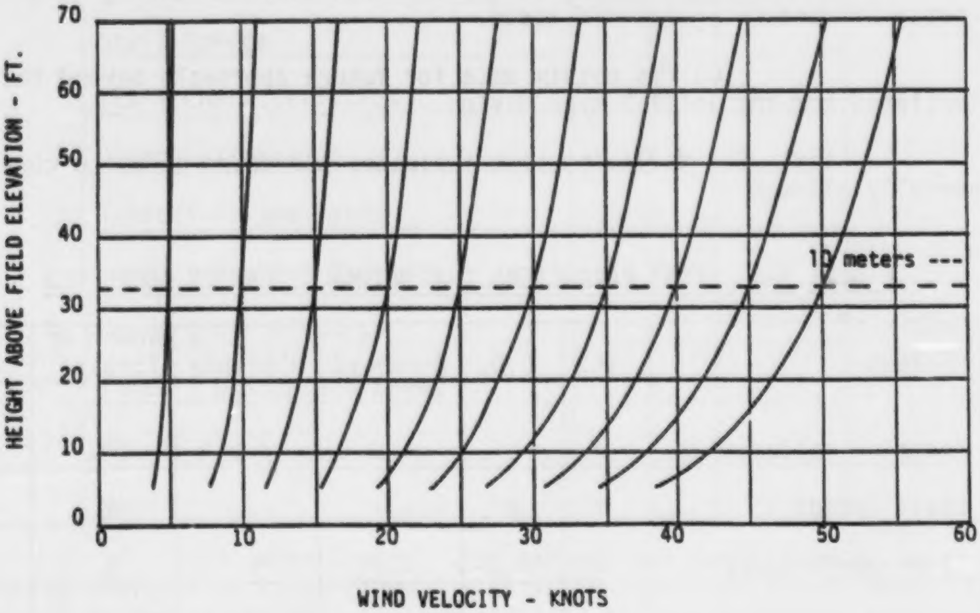
(4) Section 25.21(f) - Proof of Compliance (Wind Measurement and Corrections). The relationship between the wind measured at one height and the corresponding wind at another height may be obtained by the following equation:

$$V_{W2} = V_{W1}(H_2/H_1)^{1/7}$$

Where H = HEIGHT ABOVE THE RUNWAY SURFACE
$V_{W2}$ = Wind velocity at $H_2$
$V_{W1}$ = Wind velocity at $H_1$

This equation is presented graphically below. Values of H less than 5 ft. should not be used in this relationship.

FIGURE 3-3. WIND PROFILE VARIATION



(5) The following examples are methods of handling wind profile variation data. Other methods have also been found acceptable.

(6) Wind Profile Variation for Test Data. The performance data of airplanes should be obtained in such a manner that the effect of wind on the test data may be determined. The test wind velocity should be corrected from the recorded height above the test surface to the height of the airplane wing mean aerodynamic chord. If the wind profile variation is not measured, the variation may be calculated using the equation in paragraph (4) above.

Example: Test Data

Given:

| | |
|---|---|
| o Height of mean aerodynamic chord with airplane on surface | 8 ft. |
| o Height of wind measurement | 6 ft. |
| o Measured wind velocity | 4.8 kts. |

Results:

- o Test wind velocity with airplane 50 ft. above landing surface
  $4.8((50 + 8)/6)^{1/7} =$ 6.6 kts.
- o Test wind velocity with airplane 35 ft. above takeoff surface
  $4.8((35 + 8)/6)^{1/7} =$ 6.4 kts.
- o Test wind velocity with airplane on surface
  $4.8(8/6)^{1/7} =$ 5.0 kts.

(7) Wind Profile Variation for Airplane Flight Manual (AFM) Data. When expanding the data to the AFM conditions, the result should include the effective velocity, at the airplane's wing mean aerodynamic chord, which corresponds to the wind condition as measured at 10 meters (32.81 ft.) above the takeoff surface, and corrected for wind factors of § 25.105(d)(1).

Example: Airplane Flight Manual Data

Given:

| | |
|---|---|
| o Height of mean aerodynamic chord with airplane on surface | 8 ft. |
| o Reported head wind at 10 meters | 40.0 kts. |
| o Section 25.105(d)(1) wind factor | 0.5 |

Results:

- o Factored wind velocity with airplane 50 ft. above landing surface
  $(0.5)(40)((50 + 8)/32.81)^{1/7} =$ 21.7 kts.
- o Factored wind velocity with airplane 35 ft. above takeoff surface
  $(0.5)(40)((35 + 8)/32.81)^{1/7} =$ 20.8 kts.
- o Factored wind velocity with airplane on surface
  $(0.5)(40)(8/32.81)^{1/7} =$ 16.3 kts.

(8) Airplane Airspeed Variation Due to Wind Profile Variation With Simultaneous Speed Changes Due to Airplane Dynamic Performance. In the reduction of test data and in the expansion of such data to AFM conditions, the increase or decrease of speed due to the dynamic effect of the forces on the airplane are manifested by only the change in ground speed. These changes in speed (zero wind speed changes) may be generalized either as speed increments or speed ratios. The changes in airspeed due to wind profile are superimposed on these speed changes.

Example: Takeoff Test Data

Given:

| | |
|---|---|
| True airspeed at liftoff, $V_{LOF}$ | 144 kts. |
| True airspeed at 35 ft. above takeoff surface | 147 kts. |
| Test wind at liftoff | 5.0 kts. |
| Test wind with airplane 35 ft. above takeoff surface | 6.4 kts. |

Results:

| | |
|---|---|
| Speed change due to airplane dynamic performance, zero wind speed change $(V_{35}-V_{LOF}) = (147-6.4)-(144-5.0)$ | 1.6 kts. |

Example: Takeoff--Airplane Flight Manual Data

Given:

| | |
|---|---|
| Factored wind at liftoff | 16.3 kts. |
| Factored wind with airplane 35 ft. above takeoff surface | 20.8 kts. |
| Zero wind speed change, $(V_{35}-V_{LOF})$ | 1.6 kts. |
| Zero wind speed change, $(V_{LOF}-V_R)$ | 0.5 kts. |
| True airspeed required at 35 ft. | 150 kts. |

Results:

| | |
|---|---|
| Ground speed required at 35 ft. | 150-20.8 = 129.2 kts. |
| Ground speed at liftoff | 129.2-1.6 = 127.6 kts. |
| True airspeed at liftoff | 127.6+16.3 = 143.9 kts. |
| Ground speed at rotation | 127.6-0.5 = 127.1 kts. |
| True airspeed at rotation (for distance calculations) | 127.1+16.3 = 143.4 kts. |
| Airplane flight manual rotation speed, true airspeed | 150-0.5-1.6 = 147.9 kts. |

Note: The indicated airspeed at rotation ($V_R$) given in the AFM should be predicated on the required speed at 35 ft. minus the zero wind speed change, not including the airspeed change due to wind profile. The proper rotation speed, assuming the airplane will gain 4.5 knots due to wind profile, is 143.4 knots. However, if this airspeed increase does not materialize, the airplane will be slow by 4.5 knots at 35 ft. It is therefore more desirable to allow the airplane to attain this 4.5 knots on the ground. Any reduction in field length margin of safety by this increase in VR is adequately compensated for by the 50 percent wind factor. This also eliminates a requirement to adjust $V_R$ for wind. However, in calculating the AFM field lengths, the airspeed attained due to wind profile may be included.

Example: Landing--Airplane Flight Manual Data

Given:

| | |
|---|---|
| o Factored wind with airplane 50 ft. above landing surface | 21.7 kts. |
| o Factored wind with airplane on landing surface | 20.8 kts. |
| o Zero wind speed change for 50 ft. to touchdown $(V_{50}-V_{TD})$ | 4.0 kts. |
| o True airspeed required at 50 ft. | 130 kts. |

Results:

| | | |
|---|---|---|
| o Ground speed at 50 ft. | 130-21.7 | = 108.3 kts. |
| o Ground speed at touchdown | 108.3-4.0 | = 104.3 kts. |
| o True airspeed at touchdown | 104.3+20.8 | = 125.1 kts. |

(9) Expansion of Takeoff Data for a Range of Airport Elevations.

(i) These guidelines are applicable to expanding takeoff data above the altitude at which the basic or verifying tests were obtained.

(ii) In general, takeoff data may be extrapolated above and below the altitude at which the basic test data was obtained without additional conservatism within the following constraints.

(iii) When the basic takeoff tests are accomplished between sea level and approximately 3,000 ft., the maximum allowable extrapolation limits are 6,000 ft. above and 3,000 ft. below the test field elevation. If it is desired to extrapolate beyond these limits, one of two procedures may be employed.

(A) Extrapolation of Performance Data for a Range of Altitudes When Verifying Tests are Not Conducted. The approval of performance data for airport elevations beyond the maximum elevation permitted by basic tests may be allowed without conducting verifying tests if the calculated data include a conservative factor. This conservatism should result in an increase of the calculated takeoff distance at the desired airport elevations by an amount equal to zero percent for the highest airport elevation approved on the results of the basic tests and an additional cumulative 2 percent incremental factor for each 1,000 ft. of elevation above the highest airport elevation approved for zero percent conservatism. The 2 percent incremental factor should have a straight line variation with altitude. When performance data are calculated for the effects of altitude under this procedure, the following provisions are applicable:

(1) Previously established calculation procedures should be used, taking into account all known variables.

(2) The calibrated installed engine power for the pertinent speed and altitude ranges should be used.

(3) The brake kinetic energy limits established by airplane ground tests should not be exceeded.

(B) Extrapolation of Performance Data When Verifying Tests Are Conducted.

(1) If data approval is desired for a greater range of airport elevations, the performance may be calculated from the basic test data up to the maximum airport elevation, provided verifying tests are conducted at appropriate elevations to substantiate the validity of the calculations. The actual airplane performance data from the verifying tests should correspond closely to the calculated performance values.

(2) For the verifying tests, it has been found that normally three takeoffs at maximum weights for the elevations tested will provide adequate verification.

(3) If verifying tests substantiate the expanded takeoff data, the data may be further expanded up to 6,000 ft. above the altitude at which the verifying tests were conducted. At altitudes higher than 6,000 ft. above the verifying test altitude, the 2 percent per 1,000 ft. cumulative factor discussed in para. (A) above should be applied starting at zero percent at the verifying test altitude plus 6,000 ft.

(10) Expansion of Landing Data for a Range of Airport Elevations.

(i) For turbine powered airplanes without propellers, the landing distance data may be extrapolated to more than 6,000 ft. above the test altitude without the penalty described in paragraph (9) above, provided the true airspeed effect on the distance is accounted for.

(ii) For turbopropeller and reciprocating engine-powered airplanes, the extrapolated performance should include the conservative factor described in paragraph (9) above. This may not be necessary if it can be shown that the effects of altitude on the landing performance, as affected by propeller drag, are known from data available for the airplane configuration.

b. Procedures.

(1) The procedures are discussed in each of the following paragraphs of this AC:

10. Takeoff and Takeoff Speeds
11. Accelerate-Stop Distance
12. Takeoff Path
13. Takeoff Distance and Takeoff Run

(2) Performance Data for Multiple Flap or Additional Flap Positions. If approval of performance data is requested for flap settings at which no test data is available, the data may be obtained from interpolation of flight data obtained at no less than four flap settings which are within a constant configuration of other lift devices. If the span of flap settings is small and previously obtained data provides sufficient confidence (i.e., the shape of the curves are known and lend themselves to accurate interpolation), data from three flap settings may be acceptable.

(3) Flight Characteristics for Abnormal Configurations (Ref. § 25.671(c)).

(i) For purposes of this AC, an abnormal configuration is an operational configuration that results from a single probable failure or probable combination of failures.

(ii) Flight characteristics for abnormal configurations may be determined by test or analysis to assure that the airplane is capable of continued safe flight and landing. Flight tests, if required, should be conducted at the critical conditions of altitude, weight, c.g., and engine thrust associated with the configuration, and at the most critical airspeed between stall warning and the maximum operating airspeed as limited for the configuration.

4.-7. [RESERVED]

## 8. PROPELLER SPEED AND PITCH LIMITS - § 25.33.

a. Explanation. None.

b. Procedures. The tachometers and the airspeed indicating system of the test airplane must have been calibrated in the last six months. With those conditions satisfied, the following should be accomplished:

(1) Determine that the propeller speeds and pitch settings are safe and satisfactory during all tests that are conducted in the flight test program within the certification limits of the airplane, engine, and propeller. This includes establishing acceptable low pitch (flight idle) blade angles on turbopropeller airplanes and verifying that propeller configurations are satisfactory at $V_{MO}/M_{MO}$ to prevent propeller overspeed.

(2) Determine that the propeller speeds and pitch settings are safe and satisfactory during all tests that are conducted to satisfy the performance requirements.

(3) With the propeller governors operative and the propeller controls in full high r.p.m. position, determine that the maximum takeoff power settings do not exceed the rated takeoff r.p.m. of each engine during takeoff and climb at the best rate-of-climb speed.

(4) With the propeller governors made inoperative by mechanical means, maximum power, no-wind static r.p.m.'s must be determined. On reciprocating

engines with the propeller governors operating on the low pitch stop, the engine speeds must not exceed 103 percent of the maximum allowable takeoff r.p.m. On turbopropeller engines, the engine speeds must not exceed the maximum engine speeds allowed by engine and propeller type designs. Note which systems were disabled and how the disablement was done. If maximum takeoff power torque or sea level standard conditions cannot be obtained on the test day, the data must be corrected to these conditions by an acceptable means. A no-wind condition is considered to be a wind of 5 knots or less. The static r.p.m. should be the average obtained with a direct crosswind from the left and a direct crosswind from the right.

(5) If the above determinations are satisfactory, the low-pitch stop setting and also the high-pitch stop setting must be measured. These data may have been obtained from the propeller manufacturer and may be used provided the pitch stops have not been changed since the manufacturer delivered the propeller. If measured, the blade station should be recorded. These blade angles must be included in the Type Certificate Data Sheet.

## Section 2. PERFORMANCE

9. [RESERVED]

### 10. TAKEOFF AND TAKEOFF SPEEDS - §§ 25.105 AND 25.107 (PART 25 AS AMENDED THROUGH AMENDMENT 25-42).

a. Explanation. The primary objective of the takeoff tests required by § 25.107 is to determine the takeoff speed schedule for all takeoff configurations at all weight, altitude, and temperature conditions within the operational limits selected by the applicant. The provisions of § 25.105 are self evident and are not repeated or amplified in this discussion.

b. Procedures. Although the following speed definitions are given in terms of calibrated airspeed, the Airplane Flight Manual (AFM) presentations shall be given in terms of indicated airspeed.

(1) Section 25.107(a)(1) - Engine Failure Speed ($V_{EF}$). The engine failure speed ($V_{EF}$) is defined as the calibrated airspeed at which the critical engine is assumed to fail and must be selected by the applicant. $V_{EF}$ cannot be less than the ground minimum control speed ($V_{MCG}$) as described in §§ 25.149(e) and 25.107(a)(1).

(2) Section 25.107(a)(2) - Takeoff Decision Speed ($V_1$). The takeoff decision speed ($V_1$) may not be less than $V_{EF}$ plus the speed gained with the critical engine inoperative during the time interval between $V_{EF}$ and the instant at which the pilot recognizes the engine failure. This is indicated by pilot application of the first decelerating device such as brakes, throttles, spoilers, etc. during accelerate-stop tests, or by the first control input during $V_{MCG}$ testing. The applicant may choose the sequence of events. Refer to § 25.109 for a more complete description of RTO transition procedures and associated time delays. If it becomes evident in expansion of takeoff data for the AFM that excessive variation in $V_1$ exists, resulting from the many performance variables involved (variations of ±1.5 knots or ±100 ft. have been acceptable), then measures must be taken to ensure that scheduled performance variations are not excessive. Examples of such measures are small field length factors, or increments, and multiple web charts (accelerate-go/stop, $V_1/V_R$) for a particular configuration.

(3) Section 25.107(b) - Minimum Takeoff Safety Speed ($V_{2MIN}$).

(i) $V_{2MIN}$, in terms of calibrated airspeed, cannot be less than:

(A) 1.1 times the $V_{MCA}$ defined in § 25.149.

(B) 1.2 times $V_S$ for two-engine and three-engine turbopropeller and reciprocating engine-powered airplanes and for all turbojet airplanes that do not have provisions for obtaining significant reduction in the one-engine inoperative power-on stalling speed (i.e., boundary layer control, blown flaps, etc.).

(ii) $V_{2MIN}$ may be reduced to 1.15 times $V_S$ for turbopropeller and reciprocating engine-powered airplanes with more than three engines, and turbojet powered airplanes with adequate provisions for obtaining significant power-on stall speed reduction through the use of such things as boundary layer control and blown flaps, etc.

(iii) For propeller-driven airplanes, the difference between the two margins, based upon the number of engines installed in the airplane, is due to the fact that the application of power ordinarily reduces the stalling speed appreciably. In the case of the two-engine propeller-driven airplane, at least half of this reduction is eliminated by the failure of an engine. The difference in the required factors therefore provides approximately the same margin over the actual stalling speed under the power conditions which are obtained after the loss of an engine, no matter what the number of engines (in excess of one) may be. Unlike the propeller-driven airplane, the turbojet/turbofan powered airplane does not show any appreciable difference between the power-on and power-off stalling speed. This is due to the absence of the propeller which ordinarily induces a slipstream with the application of power causing the wing to retain its lift to a speed lower than the power-off stalling speed. The applicant's selection of the two speeds specified will influence the nature of the testing required in establishing the takeoff flight path.

(4) Section 25.107(c) - Takeoff Safety Speed ($V_2$). $V_2$ is the calibrated airspeed that is attained at or before 35 ft. above the takeoff surface after an engine failure at $V_{EF}$ using an established rotation speed ($V_R$). During the takeoff speeds demonstration, $V_2$ should be continued to an altitude sufficient to assure stable conditions beyond 35 ft. $V_2$ cannot be less than $V_{2MIN}$. $V_2$ should be substantiated by fuel cuts at $V_{EF}$, when the bulk of the engine inoperative data have been determined with Idle cuts.

(5) Section 25.107(d) - Minimum Unstick Speed ($V_{MU}$).

(i) An applicant should comply with § 25.107(d) by conducting minimum unstick speed ($V_{MU}$) determination tests with all engines operating and with one engine inoperative. During this demonstration, the takeoff should be continued until the airplane is out of ground effect. The airplane pitch attitude should not be decreased after liftoff. In lieu of conducting actual one-engine-inoperative $V_{MU}$ tests, the applicant may conduct all-engines operating $V_{MU}$ tests that simulate and account for all pertinent factors that would be associated with an actual one-engine-inoperative $V_{MU}$ test. To account fully for pertinent factors, it may be necessary to adjust the resulting $V_{MU}$ test values analytically.

(ii) The factors to be accounted for must at least include the following:

(A) Thrust/weight ratio for one-engine-inoperative range.

(B) Controllability (may be related to one-engine-inoperative free air tests, such as $V_S$, $V_{MCA}$, etc.).

(C) Increased drag due to lateral/directional control systems including devices such as wing spoilers, etc.

(D) Reduced lift due to devices such as wing spoilers used for lateral control, etc.

(E) Adverse effects of any other systems or devices on control, drag, and/or lift.

(iii) The number of $V_{MU}$ tests required may be minimized by testing only the critical all-engine and one-engine-inoperative thrust/weight ratios provided that the $V_{MU}$ speeds determined at these critical conditions are used for the range of thrust/weights appropriate to the all-engines and one-engine-inoperative configuration. The critical thrust/weight is established by correcting to the $V_{MU}$ speed, the thrust that results in the airplane achieving its limiting engine-out climb gradient at the normally scheduled speed and in the appropriate configuration.

(iv) Amendment 25-42, effective March 1, 1978, revised §§ 25.107(d) and 25.107(e)(iv) in order to permit one-engine-inoperative $V_{MU}$ to be determined by all-engine tests at the thrust/weight ratio corresponding to the one-engine-inoperative condition. As revised, § 25.107(d) specifies that $V_{MU}$ must be selected for the range of thrust/weight ratios to be certificated rather than for the all-engines operating and one-engine-inoperative conditions, as was previously required. In determining the all-engines thrust/weight ratio corresponding to the one-engine-inoperative condition, consideration should be given to trim and control drag differences between the two configurations in addition to the effect of the number of engines operating. The minimum thrust/weight to be certificated is established by correcting to the $V_{MU}$ speed, the thrust that results in the airplane achieving its limiting engine-out climb gradient in the appropriate configuration and at the normally scheduled speed.

(v) To conduct the $V_{MU}$ tests, rotate the airplane as necessary to achieve the $V_{MU}$ attitude. It is acceptable to use some additional nose-up trim over the normal trim setting during $V_{MU}$ demonstrations. $V_{MU}$ is the speed at which the weight of the airplane is completely supported by aerodynamic lift and thrust forces. Some judgment may be necessary on airplanes that have tilting main landing gear bogies. In some cases, full oleo extension has been permitted as the identification point for $V_{MU}$ speed. After liftoff the airplane should be flown at least out-of-ground effect. The airplane should demonstrate adequate controllability and light buffet may be considered acceptable.

(vi) $V_{MU}$ Testing for Airplanes Having Limited Pitch Control Authority.

(A) For some airplanes with limited pitch control authority, it may not be possible at forward c.g. and normal trim to rotate the airplane to a liftoff attitude where the airplane could otherwise perform a clean flyaway at a minimum speed had the required attitude been achieved. This may occur only over a portion of the takeoff weight range in some configurations. When limited pitch control authority is clearly shown to be the case, $V_{MU}$ test conditions may be modified to allow testing aft of the forward c.g. limit and/or with use of more airplane nose-up trim than normal. The $V_{MU}$ data determined with this procedure should be corrected to those values representative of the appropriate forward limit; the variation of $V_{MU}$ with c.g. may be assumed to be like the variation of free air stalling speed with c.g. Although the development of scheduled takeoff speeds may proceed from these corrected $V_{MU}$ data, two additional sets of tests are required to check that the relaxed $V_{MU}$ criteria have not neglected problems that might arise from operational variations in rotating airplanes with limited pitch control authority.

(B) In each of the following assurance tests, the airplane must demonstrate safe flyaway characteristics.

(1) Minimum speed liftoff will be demonstrated at the critical forward c.g. limit with normal trim. For airplanes with a cutback forward c.g. at heavy weight, two weight/c.g. conditions should be considered. The heavy weight tests should be conducted at maximum structural or maximum sea level climb-limited weight with the associated forward c.g. The full forward c.g. tests should be conducted at the highest associated weight. These tests should be conducted at minimum thrust/weight for both the simulated one-engine-inoperative test (symmetrical reduced thrust) and the all-engines case.

(2) The test technique is to hold full nose-up control column as the airplane accelerates. As pitch attitude is achieved to establish the minimum liftoff speed, pitch control may be adjusted to prevent overrotation, but the liftoff attitude should be maintained as the airplane flies off the ground, and out-of-ground effect.

(3) Resulting liftoff speeds do not affect AFM speed schedules if the test proves successful and the resulting liftoff speed is at least 5 knots below the normally scheduled liftoff speed. Adjustments should be made to the scheduled $V_R$, forward c.g., etc., if necessary, to achieve this result.

(4) This 5 knot minimum spread provides some leeway for operational variations such as mis-trim, c.g. errors, etc., that could further limit the elevator authority. This reduced minimum spread from that specified in § 25.107(e)(1)(iv) results from the reduced probability of getting into a high drag condition due to overrotation.

(vii) $V_{MU}$ Testing for Geometry Limited Airplanes.

(A) For airplanes that are geometry limited, the 110 percent of $V_{MU}$ required by § 25.107(e)(1)(iv) may be reduced to an operationally acceptable value of 108 percent on the basis that equivalent airworthiness is provided for the geometry limited airplane. Furthermore, for the use of the 108 percent of $V_{MU}$ liftoff speed, safeguards protecting the geometry limited airplane against both overrotation on the ground and in the air are to be provided. Also, to be defined as a geometry limited airplane, the applicant's airplane should be geometry limited to the extent that a maximum gross weight takeoff with the tail dragging will result in a clean liftoff and fly-away in the all-engines configuration. During such a takeoff for the all-engines-operating configuration, the resulting distance to the 35 ft. height must not be greater than 105 percent of the normal takeoff distance under similar weight, altitude, and temperature conditions before the 15 percent margin is added. Lastly, the $V_{MU}$ demonstrated must be sound and repeatable.

(B) The criteria concerning the demonstration of the geometry limited proof test with regard to capability for a clean liftoff and fly-away are as follows:

(1) The airplane's pitch attitude from a speed 96 percent of the actual liftoff speed must be within 5 percent (in degrees) of the tail dragging attitude to the point of liftoff.

(2) During the above speed range (96 to 100 percent of the actual liftoff speed), the aft under-surface of the airplane must have achieved actual runway contact. It has been found acceptable in tests for contact to exist approximately 50 percent of the time that the airplane is in this speed range.

(3) Beyond the point of liftoff to a height of 35 ft., the airplane's pitch attitude must not decrease below that at the point of liftoff, or the speed must not increase more than 10 percent.

(4) The airplane shall be at the critical thrust/weight condition, as defined in § 25.107(d), but with all engines operating.

(6) Section 25.107(e) - Rotation Speed ($V_R$).

(i) The rotation speed, ($V_R$) in terms of calibrated airspeed,must be selected by the applicant. $V_R$ has a number of constraints that must be observed in order to comply with § 25.107(e):

(A) $V_R$ may not be less than $V_1$; however, it can be equal to $V_1$ in some cases.

(B) $V_R$ may not be less than 105 percent of the air minimum control speed ($V_{MCA}$).

(C) $V_R$ must be a speed that will allow the airplane to reach $V_2$ at or before reaching 35 ft. above the takeoff surface.

(D) $V_R$ must be a speed that will result in liftoff at a speed not less than 110 percent of $V_{MU}$ (unless geometry limited) for the all-engine operating condition and not less than 105 percent of the $V_{MU}$ determined at the thrust/weight ratio corresponding to the one-engine-inoperative condition for each set of conditions such as weight, altitude, temperature, and configuration.

(ii) Early rotation, one-engine-inoperative abuse test.

(A) In showing compliance with § 25.107(e)(3), some guidance relative to the airspeed attained at the 35 ft. height during the associated flight test is necessary. As this requirement dealing with a rotation speed abuse test only specifies an early rotation ($V_R$-5 knots), it is interpreted that pilot technique is to remain the same as normally used for an engine-out condition. With these considerations in mind, it is apparent that the airspeed achieved at the 35 ft. point can be somewhat below the normal scheduled $V_2$ speed. However, the amount of permissible $V_2$ speed reduction must be limited to a reasonable amount as described below.

(B) These test criteria are applicable to all unapproved, new, basic model airplanes. They are also applicable to previously approved airplanes when subsequent abuse testing is warranted. However, for those airplanes where the criteria herein are more stringent than that previously applied, consideration will be given to permit some latitude in the testing criteria.

(C) In conducting the flight tests required by § 25.107(e)(3), the test pilot shall use a normal/natural rotation technique as associated with the use of scheduled takeoff speeds for the airplane being tested. Intentional tail or tail skid contact is not considered acceptable. Further, the airspeed attained at the 35 ft. height during this test must not be less than the scheduled $V_2$ value minus 5 knots. These speed limits should not be considered or utilized as target $V_2$ test speeds, but rather are intended to provide an acceptable range of speed departure below the scheduled $V_2$ value.

(D) In this abuse test, the engine cut should be accomplished prior to the $V_R$ test speed (i.e., scheduled $V_R$-5 knots) to allow for engine spin-down, unless this would be below the $V_{MCG}$, in which case $V_{MCG}$ should govern. The normal one-engine-inoperative takeoff distance may be analytically adjusted to compensate for the effect of the early engine cut. Further, in those tests where the airspeed achieved at the 35-ft. height is slightly less than the $V_2$-5 knots limiting value, it will be permissible, in lieu of reconducting the tests, to analytically adjust the test distance to account for the excessive speed decrement.

(iii) All-engines operating abuse tests.

(A) Section 25.107(e)(4) states that there must not be a "marked increase" in the scheduled takeoff distance when reasonably expected service variations such as early and excessive rotation and out-of-trim conditions are encountered. This has been interpreted as requiring takeoff tests with all engines operating with:

(1) An abuse on rotation speed, and

(2) Out-of-trim conditions but with rotation at the scheduled $V_R$ speed.

Note: The expression "marked increase" in the takeoff distance is defined as any amount in excess of 1 percent of the scheduled takeoff distance. Thus, the abuse tests should not result in field lengths more than 101 percent of the scheduled FAR field length.

(B) For the early rotation abuse condition with all engines operating and at a weight as near as practicable to the maximum sea level takeoff weight, it should be shown by test that when the airplane is overrotated at a speed below the scheduled $V_R$, no "marked increase" in the FAR field length will result. For this demonstration, the airplane should be rotated at a speed 7 percent or 10 knots, whichever is less, below the scheduled $V_R$. Tests should be conducted at a rapid rotation rate or should include an overrotation of 2 degrees above normal attitude after liftoff. Tail strikes during this demonstration are acceptable if they are minor and do not result in unsafe conditions.

(C) For out-of-trim conditions with all engines operating and at a weight as near as practicable to the maximum sea level takeoff weight, it should be shown that with the airplane mistrimmed, as would reasonably be expected in service, there will not be a "marked increase" in the FAR field length when rotation is initiated in a normal manner at the scheduled $V_R$ speed. The amount of mistrim used during some airplane certification programs has been ±2 units of longitudinal trim, within the takeoff trim band, as shown on the cockpit indicator. It is permissible to accept an analysis in lieu of actual testing if the analysis shows that the out-of-trim condition would present no hazardous flight characteristics nor "marked increase" in the FAR field length.

(7) Section 25.107(f) - Liftoff Speed ($V_{LOF}$). The liftoff speed ($V_{LOF}$) is defined as the calibrated airspeed at which the airplane first becomes airborne, i.e., no contact with the runway. This allows comparison of liftoff speed with tire limit speed. $V_{LOF}$ differs from $V_{MU}$ in that $V_{MU}$ is the minimum possible $V_{LOF}$ speed for a given configuration, and depending upon landing gear design, $V_{MU}$ liftoff is shown to be the point where all of the airplane weight is being supported by airplane lift and thrust forces and not any portion by the landing gear. For example, after the $V_{MU}$ speed is reached, a truck tilt actuator may force a front or rear wheel set to be in contact with the runway even though the flyoff is in progress by virtue of lift being greater than weight.

## 11. ACCELERATE-STOP DISTANCE - § 25.109.

a. Explanation. This section describes test demonstrations necessary to determine accelerate-stop distances for airplane performance required to be published in the Performance Section of the FAA approved AFM. (See Parts 121 and 135 of the FAR.)

b. The applicable Federal Aviation Regulations (FAR) are Section 25.109, as amended through Amendment 25-42, and the following:

| | |
|---|---|
| Section 25.101(f) | Airplane configuration and procedures. |
| Section 25.101(h) | Pilot retarding means time delay allowances. |
| Section 25.105 | Takeoff configuration and environmental and runway conditions. |

| | |
|---|---|
| Sections 25.107(a)(1) and (2) | Defines $V_1$ and $V_{EF}$ speeds. |
| Section 25.735 | Brakes. |
| Section 25.1301 | Function and installation. |
| Section 25.1309 | Equipment, systems, and installation. |
| Section 25.1533 | Additional operating limitations - maximum takeoff weights and minimum takeoff distances. |
| Section 25.1583(h) | FAA-approved airplane flight manual - operating limitations. |
| Section 25.1587 | FAA-approved airplane flight manual - performance information. |

c. Procedures.

(1) The following are applicable to turbine-powered airplanes with and without propellers. Accelerate-stop tests should be determined in accordance with the provisions of this paragraph.

(i) In order to establish a representative distance that would be required in the event of a rejected takeoff at or below the takeoff decision speed $V_1$, a sufficient number of test runs should be conducted for each airplane configuration desired by the applicant. (For intermediate configurations, see paragraph 3 of this AC.)

(ii) The procedures outlined in paragraphs (12) (13), and (14) below, as required by § 25.101(h)(3), apply appropriate time delays for the execution of retarding means related to the accelerate-stop operation procedures and for expansion of accelerate-stop data to be incorporated in the FAA-approved AFM.

(iii) The stopping portion of the accelerate-stop test may not utilize engine or propeller reverse thrust unless the thrust reverser system is shown to be safe, reliable, and capable of giving repeatable results.

Note: Historically, reverse thrust credit has not been utilized for certificated performance since contaminated runway braking performance has not been required in the certification process.

(2) Accelerate-stop runs at different airport elevations can be simulated at one airport elevation provided the braking speeds employed include the entire energy range that must be absorbed by the brakes. In scheduling the data for the AFM, the brake energy assumed shall not exceed the maximum demonstrated in these tests.

(3) The braking speeds referred to herein are scheduled test speeds and need not correspond to the values to be scheduled in the AFM since it is necessary to increase or decrease the braking speed to simulate the energy range and weight envelope.

(4) Unless sufficient data are available for the airplane model to account for variation of braking performance with weight, kinetic energy, lift, drag, ground speed, torque limit, etc., at least two test runs are necessary for each configuration when multiple aerodynamic configurations are being shown to have the same braking coefficient of friction. A total of at least six test runs are required. These runs should be made with the airplane weight and kinetic energy varying throughout the range for which takeoff data are scheduled. These tests are conducted on hard surfaced, dry runways.

(5) For an alternate approval with antiskid inoperative, nose wheel brakes or one main wheel brake inoperative, autobraking systems, etc., a full set of tests, as in paragraph (4) above, should normally be conducted. A lesser number of tests may be accepted for "equal or better" demonstrations or to establish small increments, or if adequate conservatism is used during testing.

(6) The maximum energy accelerate-stop demonstration should be conducted at not less than maximum takeoff weight and should be preceded by a 3-mile taxi, including three full stops using normal braking and all engines operating. Following the stop at the maximum kinetic energy level demonstration, it will not be necessary for the airplane to demonstrate its ability to taxi. The maximum kinetic airplane energy at which performance data are scheduled should not exceed the value for which a satisfactory afterstop condition exists or the value documented under Technical Standard Order TSO C26b or C26c, whichever value is less. This condition is defined as one in which fires are confined to tires, wheels, and brakes and which would not result in progressive engulfment of the remaining airplane during the time of passengers and crew evacuation. The application of fire fighting means or artificial coolants should not be required for a period of 5 minutes following the stop.

(7) In the event the applicant proposes to conduct the maximum energy RTO demonstration from a landing, a satisfactory accounting of the brake and tire temperatures that would have been generated during taxi and acceleration, required by paragraph (6), must be made.

(8) Either ground or airborne instrumentation should include means to determine the horizontal distance-time history.

(9) The wind speed and direction relative to the active runway should be determined and corrected to a height corresponding to the approximate height of the mean aerodynamic chord. (See paragraph 3 of this AC.)

(10) The accelerate-stop tests should be conducted in the following configurations:

(i) Heavy to light weight as required.

(ii) Most critical c.g. position.

(iii) Wing flaps in the takeoff position(s).

(iv) Tire pressure: before taxi and with cold tires, set to the highest value appropriate for the takeoff weight for which approval is being sought.

(v) Engine idle thrust: set at applicant's recommended upper limit or the effect of maximum idle thrust may be accounted for in data analyses.

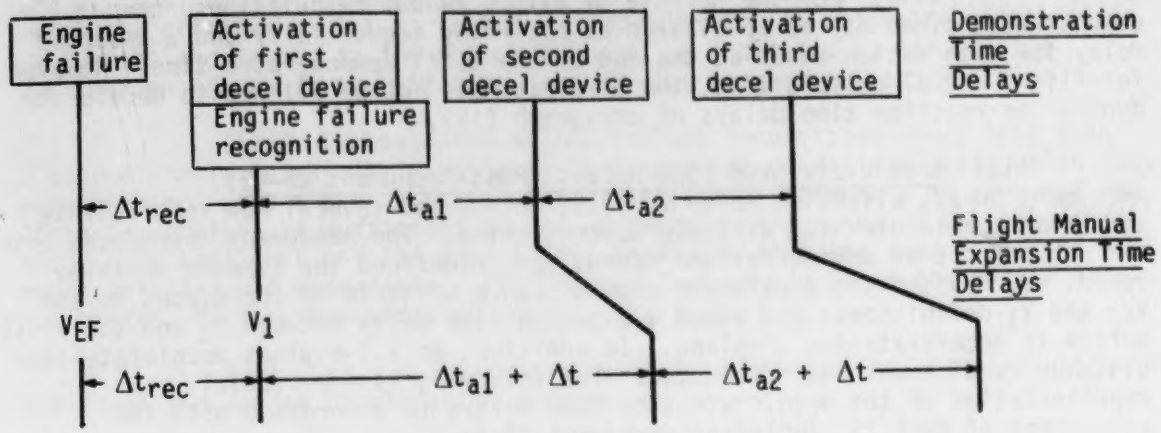
(11) Engine thrust should be appropriate to each segment of the rejected takeoff and account for thrust decay times. At the selected speed that corresponds to the required energy, the airplane is brought to a stop employing the acceptable braking means.

(i) For turbine powered airplanes without propellers, all engines should remain operative for test and AFM expansion purposes. However, it should be determined that any engine remaining at idle power for test purposes when compared to a failed engine causing an inservice rejected takeoff does not provide additional braking capabilities, mask directional control problems, etc., through the continued functioning of its hydraulic pumps or other systems.

(ii) For turbopropeller and reciprocating engine-powered airplanes conducting the engine inoperative accelerate-stop demonstration, the critical engine's propeller should be in the position it would normally assume when an engine fails and the power levers are closed. The high drag position (not reverse) of the remaining engines' propellers may be utilized provided adequate directional control can be demonstrated on a wet runway (Ref. CAM 4b.402-1(k)(2)). Simulating wet runway controllability by disconnecting the nose wheel steering has been used by some applicants. For the all-engines accelerate-stop demonstration, the high drag propeller position (not reverse) may be used on all engines.

(12) Accelerate-Stop Time Delays (Pre-Amendment 25-42). Parts 1 and 25 of the FAR, prior to Amendments 1-29 and 25-42, respectively, defined $V_1$ as the critical engine failure speed. When this definition of $V_1$ is applied to the accelerate-stop criteria of § 25.109 and the $V_1$ criteria of § 25.107(a)(2), engine failure and engine failure recognition could occur simultaneously. It was recognized that this simultaneous occurrence could not be achieved in actual operations and that defining $V_1$ as engine failure speed resulted in a conflict with § 25.101 which requires allowance for time delays in execution of procedures. In order to resolve this conflict, $V_1$ has been applied as the engine failure recognition speed and appropriate time delays developed for showing compliance with § 25.101. The following is a pictorial representation of the accelerate-stop time delays considered acceptable for compliance with § 25.101(h) as discussed above:

FIGURE 11-1. ACCELERATE-STOP TIME DELAYS
Pre Amendment 25-42


Engine failure
Activation of first decel device
Engine failure recognition
Activation of second decel device
Activation of third decel device
Demonstration Time Delays
$\Delta t_{rec}$
$\Delta t_{a1}$
$\Delta t_{a2}$
Flight Manual Expansion Time Delays
$V_{EF}$
$V_1$
$\Delta t_{rec}$
$\Delta t_{a1} + \Delta t$
$\Delta t_{a2} + \Delta t$

(i) $\Delta t_{rec}$ = engine failure recognition time. The demonstrated time from engine failure to pilot action indicating recognition of the engine failure. For AFM data expansion purposes, in order to allow a time which can be executed consistently in service, it has been found practical to use the demonstrated time or 1 second, whichever is greater. If the airplane incorporates an engine failure warning light, the recognition time includes the time increment necessary for the engine to spool down to the point of warning light activation plus the time increment from light "on" to pilot action indicating recognition of engine failure.

(ii) $\Delta t_{a1}$ = the demonstrated time interval between activation of the first and second deceleration devices.

(iii) $\Delta t_{a2}$ = the demonstrated time interval between activation of the second and third deceleration devices.

(iv) $\Delta t$ = a 1-second reaction time delay to account for inservice variations. If a command is required for another crewmember to actuate a deceleration device, a 2-second delay, in lieu of the 1-second delay, should be applied for each action. For automatic deceleration devices which are approved for performance credit for AFM data expansion, established times determined during certification testing may be used without the application of additional time delays required by this paragraph.

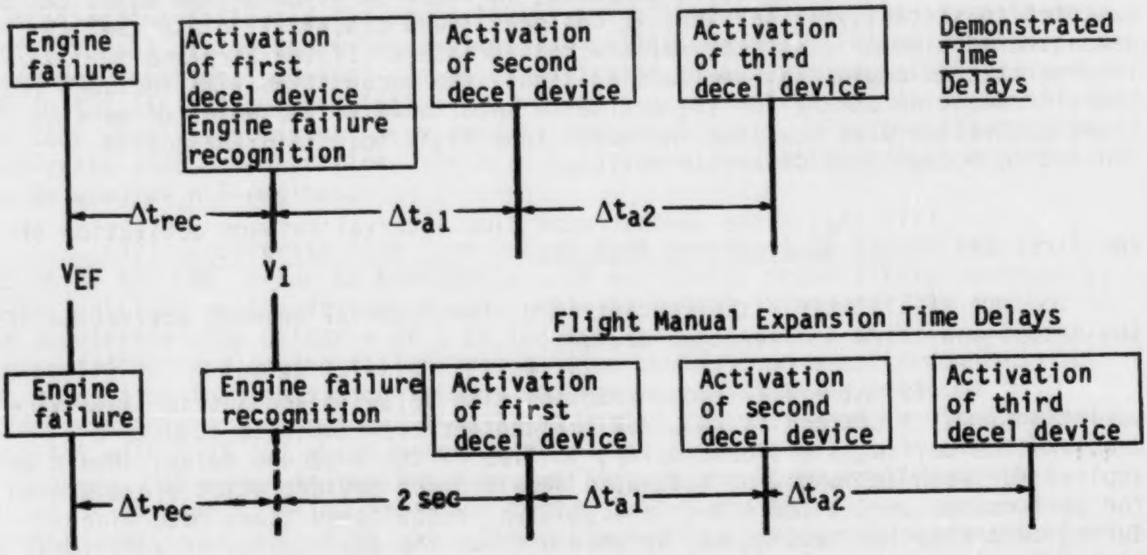
(v) The sequence for activation of deceleration devices may be selected by the applicant in accordance with § 25.101(f). If, on occasion, the desired sequence is not achieved during testing, the test need not be repeated. However, the demonstrated time interval shall be used.

(vi) If additional devices are used to decelerate the airplane, their respective demonstrated times plus any additional required time delays should be included until the airplane is in the full braking configuration.

(vii) For the purpose of flight manual calculations, the demonstrated times may be considered as occurring sequentially and a 1-second delay for each action added at the end of the total demonstrated time. However, for flight manual calculations, the airplane must not be allowed to decelerate during the reaction time delays of paragraph (iv).

(13) Accelerate-Stop Time Delays (Post-Amendment 25-42). Amendment 25-42, effective March 1, 1978, introduced several new requirements affecting accelerate-stop distance determination. The amendment introduced into the regulations an engine-failure speed, $V_{EF}$; redefined the takeoff decision speed, $V_1$; revised the accelerate-stop distance criteria to correspond to the $V_{EF}$ and $V_1$ definitions; and added a 2-second time delay between $V_1$ and the first action to decelerate the airplane. In addition, an all-engines accelerate-stop distance requirement was introduced. The following is a pictorial representation of the accelerate-stop time delays in accordance with the provisions of Part 25, including Amendment 25-42:

FIGURE 11-2. ACCELERATE-STOP TIME DELAYS
Post Amendment 25-42


Engine failure
Activation of first decel device
Engine failure recognition
Activation of second decel device
Activation of third decel device
Demonstrated Time Delays
Δt_rec
Δt_a1
Δt_a2
V_EF
V_1
Flight Manual Expansion Time Delays
Engine failure
Engine failure recognition
Activation of first decel device
Activation of second decel device
Activation of third decel device
Δt_rec
2 sec
Δt_a1
Δt_a2

(i) $\Delta t_{rec}$ - § 25.107 defines the relationship between $V_{EF}$ and $V_1$ as follows:

(ii) $V_{EF}$ is the calibrated airspeed selected by the applicant at which the critical engine is assumed to fail. $V_{EF}$ may not be less than $V_{MCG}$. $V_1$, in terms of calibrated airspeed, is the takeoff decision speed selected by the applicant; however, $V_1$ may not be less than $V_{EF}$ plus the speed gained with the critical engine inoperative during the time interval between the instant at which the critical engine is failed, and the instant at which the pilot recognizes and reacts to the engine failure, as indicated by the pilot's application of the first retarding means during accelerate-stop tests.

(iii) Demonstrated engine failure recognition times less than 1 second should be carefully reviewed to assure the conditions under which they were obtained were representative of that which may reasonably be expected to occur in service. A sufficient number of demonstrations should be conducted using both applicant and FAA test pilots to assure that the time increment is representative and repeatable. The pilot's feet should be on the rudder pedals, not brakes, during demonstration tests.

(iv) $\Delta t_{a1}$ = the demonstrated time interval between activation of the first and second deceleration devices.

(v) $\Delta t_{a2}$ = the demonstrated time interval between activation of the second and third deceleration devices.

(vi) If a command is required for another crewmember to activate a deceleration device, a 1-second delay, in addition to (iv) and (v) above, should be applied for each action. For automatic deceleration devices which are approved for performance credit for AFM data expansion, established system times determined during certification testing may be used. These established times cannot be assumed to start until after the pilot action that triggers them; that is, they cannot be triggered before the first pilot action and hence cannot begin until at least 2 seconds after $V_1$.

(vii) The sequence for activation of deceleration devices may be selected by the applicant in accordance with § 25.101(f). If, on occasion, the desired sequence is not achieved during testing, the test need not be repeated; however, the demonstrated time interval shall be used.

(viii) Figure 11-2 shows a pictorial representation of how to apply time delays with up to three deceleration devices. If more than three devices are used to decelerate the airplane, the respective demonstrated time plus a 1-second reaction time should be included for each device beyond that represented pictorially in Figure 11-2 until the airplane is in the full braking configuration.

(14) All-Engine Accelerate-Stop (Post Amendment 25-42). The time delays of paragraph (13) apply to the all-engines accelerate-stop requirement of § 25.109(a)(2) after $V_1$.

(15) The procedures used to determine accelerate-stop distance must be described in the performance section of the AFM.

## 12. TAKEOFF PATH - § 25.111.

### a. Section 25.111(a).

(1) Explanation.

(i) The takeoff path requirements of § 25.111, and the reductions required of the gross path by § 25.115 are established so that the AFM performance can be used in making necessary decisions relative to takeoff weights when obstacles are present. Such considerations are also a requirement by § 121.189 when operation is conducted under that Part.

(ii) The required performance is provided in AFMs by either pictorial paths at various thrust-to-weight conditions with corrections for wind, or by a series of charts for each segment along with a procedure for connecting these segments into a continuous path.

(2) Procedures.

(i) Section 25.111(a) requires that the actual takeoff path (from which the AFM net takeoff flight path is derived) extend to the higher of where the airplane is 1,500 ft. above the takeoff surface or to the altitude at which the transition to enroute configuration is complete and a speed is reached where compliance with the final segment requirements of § 25.121(c) can be met. Section 25.115(b) allows termination of the AFM net flight path below 1,500 ft. in some cases.

(ii) The AFM should contain information required to show compliance with the climb requirements of §§ 25.111 and 25.121(c). This should include information related to the transition from the takeoff configuration and speed to the final segment configuration and speed. The effects of changes from takeoff thrust to maximum continuous thrust should also be included.

(iii) Generally the AFM shows takeoff paths which at low thrust to weight include acceleration segments between 400 and 1,500 ft. and end at 1,500 ft., and at high thrust to weight extending considerably higher than 1,500 ft. above the takeoff surface. On some airplanes, the takeoff speed schedules and/or flap configuration do not require acceleration below 1,500 ft., even at limiting performance gradients.

(iv) The § 25.115(b) net takeoff flight path, required by § 25.1587(b) to be included in the AFM, need not extend to the altitude specified in § 25.111(a). It may be terminated at a height, generally called "NET HEIGHT," that corresponds to the actual airplane height, generally called "GROSS HEIGHT," which complies with the altitude specified in § 25.111(a).

### b. Section 25.111(a)(1)- Takeoff Path Thrust Conditions.

(1) Explanation. The gross takeoff path established from continuous demonstrated takeoffs must at all points represent the actual expected performance, or be conservative per §§ 25.111(d)(2) and 25.111(d)(4) if the path is constructed by the segmental method.

(2) Procedures.

(i) To be assured that the predicted gross takeoff path is representative of actual performance, the thrust used in its construction must comply with § 25.101(c). This requires, in part, that the thrust be based on the particular ambient atmospheric conditions that are assumed to exist along the path. Standard lapse rate for ambient temperature is specified in Part 1 of the FAR under "Standard Atmosphere" and should be used for thrust determination associated with each pressure altitude during the climb.

(ii) In accordance with § 25.111(c)(4), the thrust up to 400 ft. above the takeoff surface must represent the thrust available along the path resulting from the power lever setting established during the initial ground roll in accordance with AFM procedures. This resulting thrust may be less than that available from the rated inflight setting schedule.

(iii) A sufficient number of takeoffs, to at least the altitude above the takeoff surface scheduled for $V_2$ climb, should be made to establish the fixed power lever thrust lapse. An analysis may be used to account for various engine bleeds, e.g. ice protection, air conditioning, etc. In some airplanes the thrust growth characteristics are such that less than full rated thrust must be used for AFM takeoff power limitations and performance. This is to preclude engine limitations from being exceeded during the takeoff climbs to 400 ft. above the takeoff surface.

(iv) Engine thrust lapse with speed and altitude during the takeoff and climb, at fixed power lever settings, can be affected by takeoff pressure altitude.

(v) Most turbine engines are sensitive to crosswind or tailwind conditions when setting takeoff power under static conditions and may stall or surge. To preclude this problem, it is acceptable to establish a "rolling" takeoff thrust setting procedure, provided the AFM takeoff field length and the takeoff thrust setting charts are based on this procedure. A typical test procedure is as follows:

(A) After stopping on the runway, set an intermediate power on all engines (selected by applicant).

(B) Release brakes and advance power levers.

(C) Set target power setting as rapidly as possible prior to reaching 60 to 80 knots.

(vi) If the applicant wishes to use a different procedure, it should be evaluated and, if acceptable, the procedure should be reflected in the AFM.

c. Section 25.111(a)(2) - Engine Failure.

(1) Explanation.

(i) Since the regulations cannot dictate what type of engine failures may actually occur, it could be assumed that the engine failure required by the regulation occurs catastrophically. Such a failure would cause the thrust to drop immediately with the associated performance going from all engines to engine inoperative at the point of engine failure.

(ii) This conservative rationale notwithstanding, there is basis for assuming that the failed engine thrust will not decay immediately. Unlike reciprocating engines, the locking-up of a jet engine fan without causing the engine to separate from the airplane is highly unlikely. Separation of the engine or fan, or fan disintegration, would remove weight and/or the ram drag included in the engine inoperative performance, providing compensation for the immediate thrust loss.

(iii) With these considerations it may be acceptable to utilize the transient thrust as the failed engine spools down at $V_{EF}$. The thrust time history used for data reduction and expansion should be substantiated by test results.

(2) Procedures. If transient thrust credit is used during engine failure in determining the accelerate-go AFM performance, sufficient tests should be conducted utilizing actual fuel cuts to establish the thrust decay as contrasted to idle engine cuts.

d. Section 25.111(a)(3) - Airplane Acceleration.

(1) Explanation. None.

(2) Procedures. None.

e. Section 25.111(b) - Airplane Rotation and Gear Retraction.

(1) Explanation. None.

(2) Procedures. None.

f. Section 25.111(c)(1) - Takeoff Path Slope.

(1) Explanation.

(i) The establishment of a horizontal segment, as part of the takeoff flight path, is considered to be acceptable, per § 25.115(c), for showing compliance with the positive slope required by § 25.111(c)(1).

(ii) The net takeoff flight path is the flight path used to determine the airplane obstacle clearance for turbine powered airplanes (§ 121.189(d)(2)). Section 25.115(b) states the required climb gradient reduction to be applied throughout the flight path for the determination of the net flight path, including the level flight acceleration segment. Rather than decrease the level flight path by the amount required by § 25.115(b), § 25.115(c) allows the airplane to maintain a level net flight path during acceleration but with a reduction in acceleration equal to the gradient decrement required by § 25.115(b). By this method, the applicant exchanges altitude reduction for increased distance to accelerate in level flight in determination of the level flight portion of the net takeoff path.

(2) Procedures.

(i) The level acceleration segment in the AFM net takeoff profile should begin at the same horizontal distance along the takeoff flight path that the gross climb segment reaches the AFM specified acceleration height.

(ii) The AFM acceleration height should be presented in terms of pressure altitude increment above the takeoff surface. This information should allow the establishment of the pressure altitude "increment" ($\Delta hp$) for off-standard ambient temperature so that the $\Delta$ geometric height required for obstacle clearance is assured. For example:

Given:

- o Takeoff surface pressure altitude (hp) = 2,000 ft.
- o Airport std. temp. abs. ($T_S$) = 11°C+273.2 = 284.2°k
- o Airport ambient temp. abs. ($T_{AM}$) = -20°C+273.2 = 253.2°k
- o $\Delta$ Geometric height required ($\Delta h$) = 1,700 ft. above the takeoff surface

Find:

- o Pressure altitude increment ($\Delta hp$) above the takeoff surface
  $\Delta hp = \Delta h(T_S/T_{AM})$ = 1,700 ft. (284.2°k/253.2°k)
  $\Delta hp$ = 1,908 ft.

g. Section 25. 111(c)(2) - Takeoff Path Speed.

(1) Explanation.

(i) It is intended that the airplane be flown at a constant indicated airspeed to at least 400 ft. above the takeoff surface. This speed must meet the constraints on $V_2$ of §§ 25.107(b) and (c).

(ii) The specific wording of § 25.111(c)(2) should not be construed to imply that above 400 ft. the airspeed may be reduced below $V_2$, but instead that acceleration may be commenced.

(2) Procedures.

(i) For those airplanes that take advantage of reduced stall speeds at low pressure altitude, the scheduling of $V_2$ should not be factored against the stall speed obtained at the takeoff surface pressure altitude. Such a procedure would result in a reduced stall speed margin during the climb, which would be contrary to the intent of § 25.107(b).

(ii) For those airplanes mentioned in paragraph (i), the $V_2$ should be constrained, in addition to the requirements of § 25.107(b) and (c), by the stall speed 1,500 ft. above the takeoff surface. Weight reduction along the takeoff path, due to fuel burn, may be considered in the calculation of the stall speed ratios provided such is well established. However, many applicants have measured stall speeds at 10,000 to 15,000 ft., which provides stall margin conservatism at lower takeoff field pressure altitudes.

### h. Section 25.111(c)(3) - Required Gradient.

(1) Explanation. None.

(2) Procedures. None.

### i. Section 25.111(c)(4) - Configuration Changes.

(1) Explanation.

(i) The intent of this requirement is to permit only those crew actions that are conducted routinely to be used in establishing the engine inoperative takeoff path. The power levers may only be adjusted early during the takeoff roll, as discussed under § 25.111(a)(1), and then left fixed until at least 400 ft. above the takeoff surface.

(ii) Simulation studies and accident investigations have shown that when heavy workload occurs in the cockpit, as with an engine loss during takeoff, the crew might not advance the operative engines to avoid the ground even if the crew knows the operative engines have been set at reduced power. This same finding applies to manually feathering a propeller. The landing gear may be retracted, however, as this is accomplished routinely once a positive rate of climb is observed. This also establishes the delay time to be used for data expansion purposes.

(2) Procedures.

(i) To permit the takeoff to be conducted using less than rated power, automatic power advance devices have been approved. These devices are fully discussed in a proposed change to Part 25 (49 FR 18240; 4/27/84).

(ii) To permit the takeoff to be based on a feathered propeller up to 400 ft. above the takeoff surface, automatic propeller feathering devices have been approved. Drag reduction for a manually feathered propeller is permitted for flight path calculations only after reaching 400 ft. above the takeoff surface.

### j. Section 25.111(d) - Takeoff Path Construction.

(1) Explanation. This regulation should not be construed to mean that the takeoff path be constructed entirely from a continuous demonstration or entirely from segments. To take advantage of ground effect, typical AFM takeoff paths utilize a continuous takeoff path from $V_{LOF}$ to the gear up point,

covering the range of thrust-to-weight ratios. From that point free air performance, in accordance with § 25.111(d)(2), is added segmentally. This methodology may yield an AFM flight path that is steeper with the gear down than up.

(2) Procedures. The AFM should include the procedures necessary to achieve this performance.

k. Section 25.111(d)(1) - Takeoff Path Segment Definition.

(1) Explanation. None.

(2) Procedures. None.

l. Section 25.111(d)(2) - Takeoff Path Segment Conditions.

(1) Explanation. The subject paragraph states "The weight of the airplane, the configuration, and the power or thrust setting must be constant throughout each segment and must correspond to the most critical condition prevailing in the segment." The intent is that for simplified analysis the performance must be based on that available at the most critical point in time during the segment, not that the individual variables (weight, approximate thrust setting, etc.) should each be picked at its most critical value and then combined to produce the performance for the segment.

(2) Procedures. The performance during the takeoff path segments should be obtained using one of the following methods:

(i) The critical level of performance as explained in paragraph (1).

(ii) The average performance during the segment.

(iii) The actual performance variation during the segment.

m. Section 25.111(d)(3) - Segmented Takeoff Path Ground Effect.

(1) Explanation. See explanation under § 25.111(d). Additionally, this requirement does not intend the entire flight path to necessarily be based upon out-of-ground-effect performance simply because the continuous takeoff demonstrations have been broken into sections for data reduction expediency. For example, if the engine inoperative acceleration from $V_{EF}$ to $V_R$ is separated into a thrust decay portion and a windmilling drag portion, the climb from 35. ft. to gear up does not necessarily need to be based upon out-of-ground-effect performance.

(2) Procedures. None

n. Section 25.111(d)(4) - Segmented Takeoff Path Check.

(1) Explanation. None.

(2) Procedures. If the construction of the takeoff path from brake release to out-of-ground-effect contains any portions that have been segmented, (e.g., airplane acceleration segments of all-engines and one-engine inoperative), the path should be checked by continuous demonstrated takeoffs. A sufficient number of these, employing the AFM established takeoff procedures and speeds and covering the range of thrust-to-weight ratios, should be made to ensure the validity of the segmented takeoff path. The continuous takeoff data should be compared to takeoff data calculated by AFM data procedures but using test engine thrusts and test speeds.

o. Section 25.111(e) - Flight Path With Standby Power Rocket Engines. (RESERVED).

## 13. TAKEOFF DISTANCE AND TAKEOFF RUN - § 25.113.

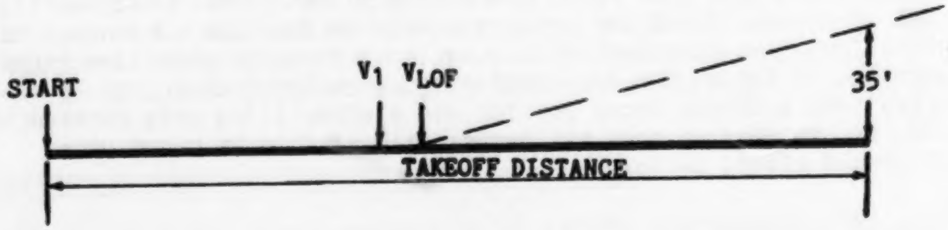
a. Takeoff Distance - § 25.113(a).

(1) Explanation.

(i) The takeoff distance is either of the two distances depicted in (A) or (B) below, whichever is greater. The distances indicated below are measured horizontally from the main landing gears at initial brake release to that same point on the airplane when the lowest part of the departing airplane is 35 ft. above the surface of the runway.

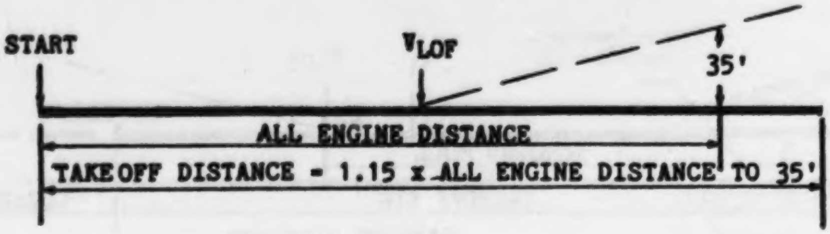
(A) The distance measured to 35 ft. with a critical engine failure recognized at $V_1$.

FIGURE 13-1. TAKEOFF DISTANCE
Critical Engine Failure Recognized at $V_1$



(B) One hundred fifteen (115) percent of the distance measured to 35 ft. with all engines operating.

FIGURE 13-2. TAKEOFF DISTANCE
All Engines Operating



(ii) The takeoff procedure adopted snould be reflected in the takeoff distance.

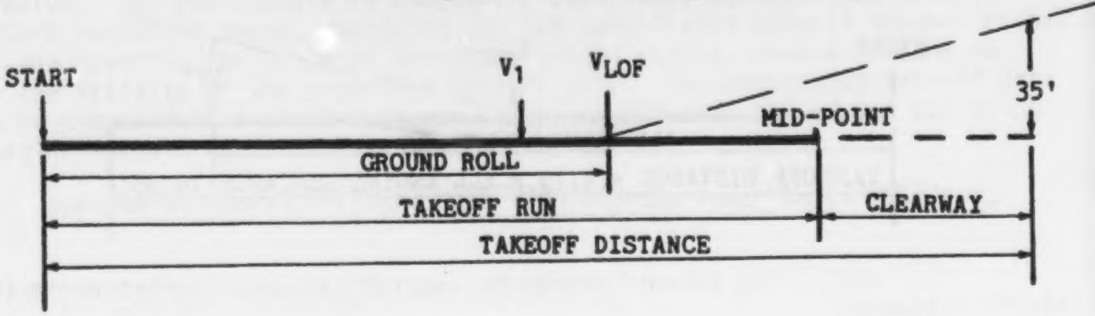
b. Takeoff Run - § 25.113(b).

(1) Explanation.

(i) Takeoff run is a term used for the runway length when the takeoff distance includes a clearway (i.e., where the accelerate-go distance does not remain entirely over the runway), and the takeoff run is either of the two distances depicted in (A) or (B) below, whichever is greater. These distances are measured as described in § 25.113(a). When using a clearway to determine the takeoff run, no more than one half of the air distance from $V_{LOF}$ to $V_{35}$ may be flown over the clearway.

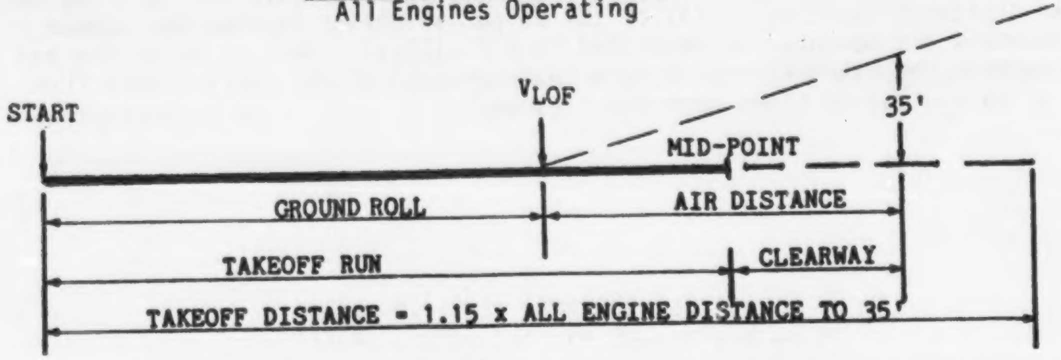
(A) The distance from start of takeoff roll to the mid-point between liftoff and the point at which the airplane attains a height of 35 ft. above the takeoff surface, with a critical engine failure recognized at $V_1$.

FIGURE 13-3. TAKEOFF RUN
Critical Engine Failure Recognized at $V_1$


START
$V_1$
$V_{LOF}$
MID-POINT
35'
GROUND ROLL
TAKEOFF RUN
CLEARWAY
TAKEOFF DISTANCE

(B) One hundred fifteen (115) percent of the distance from start of roll to the mid-point between liftoff and the point at which the airplane attains a height of 35 ft. above the takeoff surface, with all engines operating.

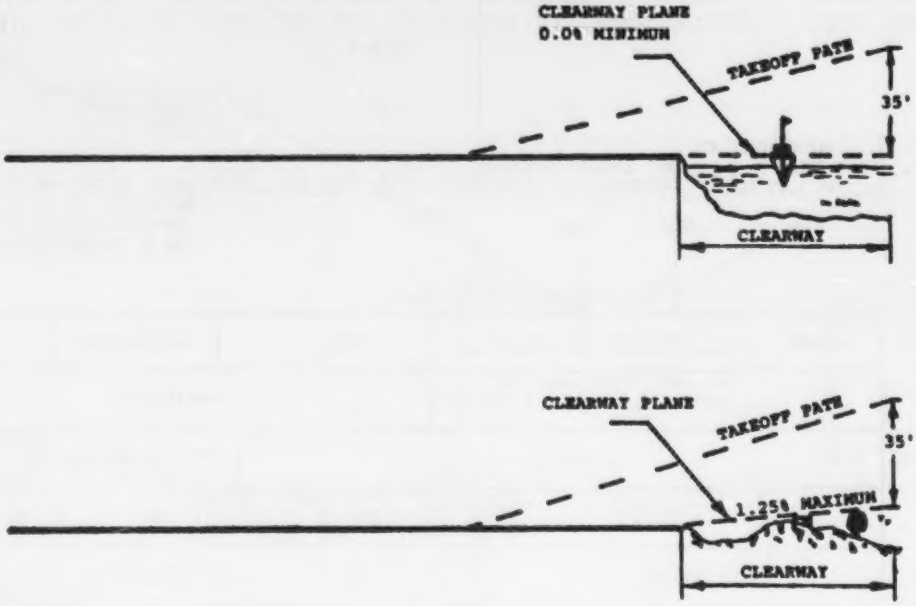
FIGURE 13-4. TAKEOFF RUN
All Engines Operating


START
$V_{LOF}$
MID-POINT
35'
GROUND ROLL
AIR DISTANCE
TAKEOFF RUN
CLEARWAY
TAKEOFF DISTANCE = 1.15 x ALL ENGINE DISTANCE TO 35'

(ii) There may be situations in which the one-engine-inoperative condition (paragraph A) would dictate one of the distance criteria, takeoff run (required runway) or takeoff distance (required runway plus clearway), while the all-engines operating condition (paragraph B) would dictate the other. Therefore, both conditions should be considered.

(iii) For the purpose of establishing takeoff distances and takeoff runs, the clearway plane is defined in Part 1 of the FAR. The clearway is considered to be part of the takeoff surface, and the 35 ft. height may be measured from that surface.

FIGURE 13-5. CLEARWAY PROFILES



(iv) The profile shows no fixed obstacle projecting above the clearway plane. However, the airport authorities must have control of the movable obstacles in this area to insure that no flight will be initiated using a clearway unless it is determined with certainty that no movable obstacles will exist within the clearway when the airplane flies over.

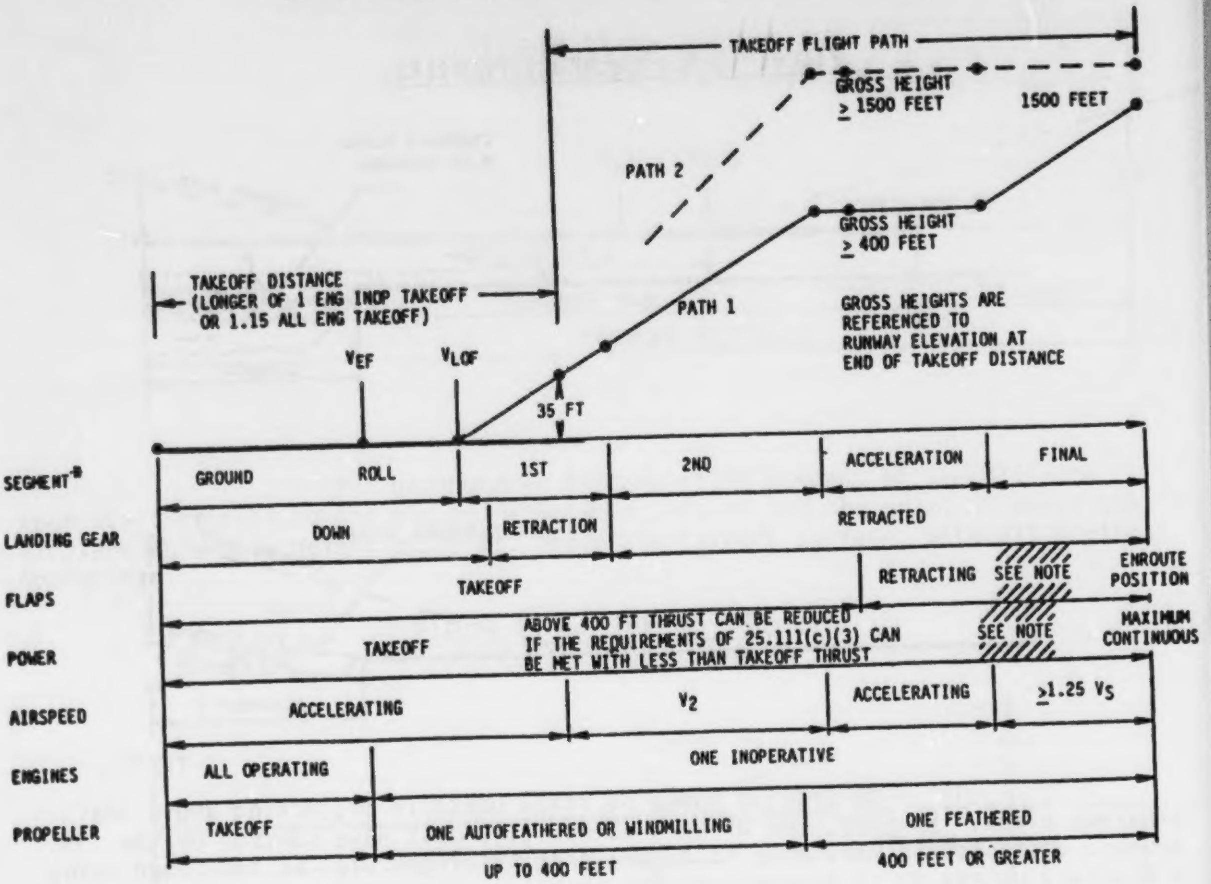
## 14. TAKEOFF FLIGHT PATH - § 25.115.

### a. Takeoff Flight Path - § 25.115(a).

(1) Explanation. The takeoff flight path begins at the end of the takeoff distance and at a height of 35 ft. above the takeoff surface and ends when the airplane's gross height is the higher of 1,500 ft. above the takeoff surface or at an altitude at which the configuration and speed have been achieved where the requirements of § 25.121(c) can be met. See paragraph 12 of this AC (§ 25.111) for additional discussion.

(2) Procedures.

FIGURE 14-1. TAKEOFF SEGMENTS & NOMENCLATURE


TAKEOFF FLIGHT PATH
GROSS HEIGHT
≥ 1500 FEET
1500 FEET
PATH 2
GROSS HEIGHT
≥ 400 FEET
TAKEOFF DISTANCE
(LONGER OF 1 ENG INOP TAKEOFF
OR 1.15 ALL ENG TAKEOFF)
PATH 1
GROSS HEIGHTS ARE
REFERENCED TO
RUNWAY ELEVATION AT
END OF TAKEOFF DISTANCE
V_EF
V_LOF
35 FT
SEGMENT*
GROUND
ROLL
1ST
2ND
ACCELERATION
FINAL
LANDING GEAR
DOWN
RETRACTION
RETRACTED
FLAPS
TAKEOFF
RETRACTING
SEE NOTE
ENROUTE
POSITION
POWER
TAKEOFF
ABOVE 400 FT THRUST CAN BE REDUCED
IF THE REQUIREMENTS OF 25.111(c)(3) CAN
BE MET WITH LESS THAN TAKEOFF THRUST
SEE NOTE
MAXIMUM
CONTINUOUS
AIRSPEED
ACCELERATING
V2
ACCELERATING
≥1.25 VS
ENGINES
ALL OPERATING
ONE INOPERATIVE
PROPELLER
TAKEOFF
ONE AUTOFEATHERED OR WINDMILLING
ONE FEATHERED
UP TO 400 FEET
400 FEET OR GREATER

Note: The final takeoff segment will usually begin with the airplane in the enroute configuration and with maximum continuous thrust, but it is not required that these conditions exist until the end of the takeoff path when compliance with § 25.121(c) is shown. The time limit on takeoff thrust cannot be exceeded.

*Segments as defined by § 25.121.

b. Net Takeoff Flight Path - §§ 25.115(b) and (c).

(1) Explanation.

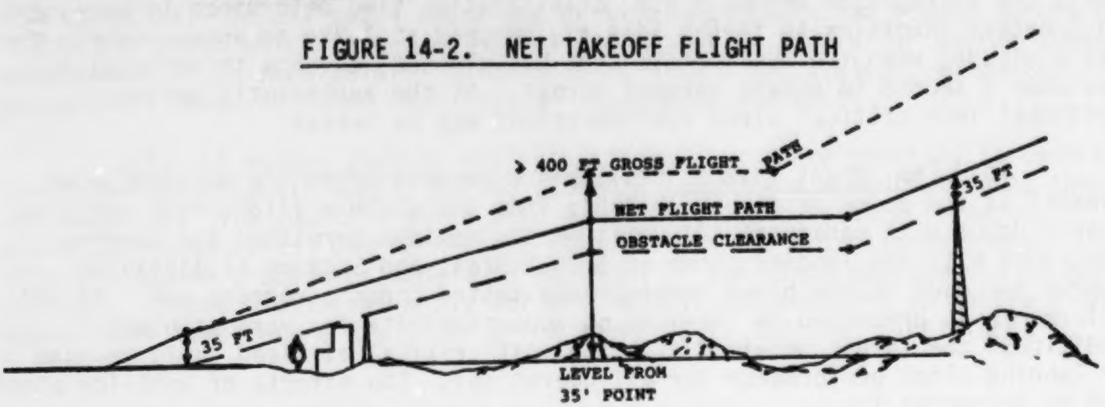
(i) The net takeoff flight path is the actual (gross) path diminished by a gradient of 0.8 percent for two-engine airplanes, 0.9 percent for three-engine airplanes, and 1.0 percent for four-engine airplanes.

(ii) For the level flight acceleration segment, these prescribed gradient reductions may be applied as an equivalent reduction in acceleration in lieu of reduction in net flight path. See paragraph 12 (§ 25.111) of this AC for additional discussion.

(iii) SR-422B and § 121.189(d)(1) require that no airplane may take off at a weight in excess of that shown in the AFM to correspond with a net takeoff flight path which clears all obstacles, either by at least a height of 35 ft. vertically or by at least 200 ft. horizontally within the airport boundaries, and by at least 300 ft. horizontally after passing beyond the boundaries.

(2) Procedures.

FIGURE 14-2. NET TAKEOFF FLIGHT PATH



15. [RESERVED]

## 16. LANDING CLIMB: ALL-ENGINES-OPERATING - § 25.119.

a. Explanation. Section 25.119(a) states that the engines are to be set at the power or thrust that is available 8 seconds after initiation of movement of the power or thrust controls from minimum flight idle to the takeoff position. The procedures given are for the determination of this maximum thrust for showing compliance with the climb requirements of § 25.119.

b. Procedures.

(1) Trim engines to minimum trim to be defined in the airplane maintenance manual.

(2) At the most adverse test altitude, not to exceed the maximum field elevation for which certification is sought plus 1,500 ft., and at the most adverse bleed configuration expected in normal operations, stabilize the airplane in level flight with symmetrical power on all engines, landing gear down, flaps in the landing position, at a speed of $1.3V_{SO}$. Retard the throttle(s) of the test engine(s) to flight idle and determine the time to reach stabilized r.p.m.,as defined below, for the test engine(s) while maintaining

level flight or the minimum rate of descent obtainable with the thrust of the remaining engine(s) not greater than maximum continuous thrust (MCT). Engine flight idle r.p.m. is considered to be stabilized when the initial rapid deceleration of all rotors is completed. This has usually been 8-20 seconds. This can be determined in the cockpit as the point where rapid movement of the tachometer ceases. For some airplanes it may be desirable to determine the deceleration time from plots of r.p.m. versus time.

(3) For the critical air bleed configuration, stabilize the airplane in level flight with symmetric power on all engines, landing gear down, flaps in the landing position, at a speed of $1.3V_{SO}$ simulating the estimated minimum climb limiting landing weights at an altitude sufficient above the selected test altitude so that time for descent to the test altitude with all throttles closed equals the appropriate engine r.p.m. stabilization time determined in paragraph (2). Retard throttles to flight idle and descend at $1.3V_S$ to approximately the test altitude; when the appropriate time has elapsed, advance throttle(s) in less than 1 second to obtain takeoff thrust. At the applicant's option, additional less critical bleed configurations may be tested.

(4) The thrust that is available 8 seconds after the initiation of movement of the power or thrust controls from the minimum flight idle position, in accordance with paragraph (3), will be the maximum permitted for showing compliance with the landing climb of § 25.119(a), and Section 4T.119(a) of SR-422B for each of the bleed combinations tested under paragraph (3). If AFM performance is presented so there is no accountability for various bleed conditions, the thrust obtained with the most critical airbleed shall be used for landing climb performance for all operations. The effects of anti-ice bleed must be accounted for.

## 17. CLIMB: ONE-ENGINE-INOPERATIVE - § 25.121.

a. Explanation. None.

b. Procedures.

(1) Two methods for establishing the one critical-engine-inoperative climb performance follow:

(i) Reciprocal heading climbs are conducted at several thrust-to-weight conditions from which the performance for the AFM is extracted. These climbs are flown with the wings nominally level. Reciprocal climbs may not be necessary if inertial corrections are applied to account for wind gradients.

(ii) Drag polars and engine-out yaw drag data are obtained for expansion into AFM climb performance. These data are obtained with the wings nominally level. Reciprocal heading check climbs are conducted to verify the predicted climb performance. These check climbs may be flown with the wings maintained in a near level attitude. Reciprocal climbs may not be necessary if inertial corrections are applied to account for wind gradients.

(2) If full rudder with wings level cannot maintain constant heading, small bank angles into the operating engine(s), with full rudder, should be used

to maintain constant heading. Unless the landing lights automatically retract with engine failure, testing should be conducted with the lights extended for § 25.121(a) Takeoff; landing gear extended, § 25.121(b) Takeoff; landing gear retracted, and § 25.121(d) Approach.

(3) The climb performance tests with landing gear extended in accordance with § 25.121(a) should be conducted with the landing gear and gear doors extended in the most unfavorable in-transit drag position. It has been acceptable to consider that the critical configuration is associated with the largest frontal area. For the landing gear, it usually exists with no weight on the landing gear. For gear doors, it is usually with all the gear doors open. If it is evident that a more critical transitional configuration exists, such as directional rotation of the gear, testing should be conducted in that configuration. In all cases where the critical configuration occurs during a transition phase which cannot be maintained except by special or extraordinary procedures, it is permissible, in accordance with § 25.21(a)(1), to apply corrections based on other test data or acceptable analysis.

(4) If means, such as variable intake doors, are provided to control powerplant cooling air supply during takeoff, climb, and enroute flight, they should be set in a position which will maintain the temperature of major powerplant components, engine fluids, etc., within the established limits. The effect of these procedures should be included in the climb performance of the airplane. These provisions apply for all ambient temperatures up to the highest operational temperature limit for which approval is desired. (Reference § 25.1043.)

(5) The latter part of § 25.121(b)(1) which states "unless there is a more critical power operating condition existing later along the flight path" is intended to cover those cases similar to where a wet engine depletes its water and reverts to dry-engine operation. This is not intended to cover normal altitude thrust lapse rates. (Reference preamble to SR-422A.)

(6) Section 25.121(d) requires that the stalling speed for the approach configuration, landing gear retracted, not exceed 110 percent of the stalling speed for the related landing configuration, landing gear extended. This stall speed ratio requirement is to ensure that an adequate margin above the stall speed in the selected approach configuration is maintained during flap retraction. To achieve this stall speed spread requirement, it is permissible to arbitrarily increase the landing flap stalling speed, $V_{SO}$, to show compliance. The AFM must, however, base the landing speed on the increased stalling speed, and the landing distance demonstrations and the AFM landing field length requirements must also be predicated on the increased speed. The stall warning requirements of § 25.207 must be established for the adjusted stalling speed. However, the § 25.203 stall characteristics requirements must still be met at the normal stall speed.

## 18. ENROUTE FLIGHT PATHS - § 25.123.

a. Explanation. This guidance is intended for showing compliance with the requirements of § 25.123 and application to the operating requirements of

§§ 121.191 and 121.193 which specify the clearances over terrain and obstructions required of the net enroute flight paths subsequent to the failure of one or two engines.

b. Procedures.

(1) Sufficient enroute climb performance data should be presented in the AFM to permit the determination of the net climb gradient and the net flight path in accordance with §§ 25.123(b) and (c) for all gross weights, altitudes, and ambient temperatures within the operating limits of the airplane.

(2) Fuel Consumption Accountability. The effect of the variation of the airplane's weight along the flight path due to the progressive consumption of fuel may be taken into account using fuel flow rates obtained from airplane manufacturers' test data. If measured fuel flow data is not available, a conservative fuel flow rate not greater than 80 percent of the engine specification flow rate at maximum continuous thrust (MCT) may be used.

(3) The procedures and flight conditions upon which the enroute flight path are based should be provided to the flightcrew. Fuel dumping may be required to achieve the required performance. A conservative analysis should be used in taking into account the ambient conditions of temperature and wind existing along the flight path. All performance should be based on the net flight path, MCT on the operating engine(s), and fuel used should be based on fuel which would be used for the net flight path.

## 19. LANDING - § 25.125.

a. Explanation.

(1) The landing distance is the horizontal distance from the point at which the main gear of the airplane is 50 ft. above the landing surface (treated as a horizontal plane through the touchdown point) to the point at which the airplane is brought to a stop. (For water landings, a speed of approximately 3 knots is considered "stopped.") In this AC, the distance is treated in two parts: the airborne distance from 50 ft. to touchdown, and the ground distance from touchdown to stop. The latter may be further subdivided into a transition phase and a full braking phase if the applicant prefers this method of analysis.

(2) The term $V_{REF}$ used in this AC means the landing threshold speed (i.e., speed at 50 ft. height) scheduled in the AFM for normal operations. The minimum value of $V_{REF}$ is specified in § 25.125(a)(2) as $1.3V_S$, which provides an adequate margin above the stall speed to allow for likely speed variations during an approach in low turbulence. If the landing demonstrations are unable to show the acceptability of the minimum approach speed and the tests are predicated on the use of an approach speed, $V_{REF}$ greater than the minimum $1.3V_S$, the landing distance data presented in the AFM must be based upon the higher approach speed.

(3) The engines should be set to the high side of the idle trim band or the effect of the idle thrust must be accounted for during the analysis and expansion of the test results.

b. Procedures for Determination of the Airborne Distance. Three acceptable means of compliance are described in paragraphs (1), (2), and (3) below. These differ from the "traditional" method in which steep approaches and high touchdown sink rates were permitted. Such a demonstration of maximum performance is no longer considered acceptable. However, the distances obtained using that method have resulted in a satisfactory operational safety record. The methods given here allow credit for the amount of testing which the applicant is prepared to conduct such that if he chooses (3), the most complex, distances typical of those from the "traditional" method should be obtained, but without incurring the associated risks during testing.

Note. If it is determined that the constraints on approach angle and touchdown rate-of-sink described in paragraphs (2) and (3) below are not appropriate due to novel or unusual features of future transport category airplane design, new criteria may be established. Such a change would be acceptable only if it is determined that an equivalent level of safety to existing performance standards and operational procedures is maintained.

(1) Experience shows an upper bound to the Part 25 zero-wind airborne distances achieved in past certifications and, similarly, a minimum speed loss. These are approximated by the following:

Air Distance (feet) = $1.55 (V_{REF}-80)^{1.35}+800$
where $V_{REF}$ is in knots TAS

Touchdown Speed = $V_{REF}-3$ knots

An applicant may choose to use these relationships to establish landing distance in lieu of measuring airborne distance and speed loss.

(2) If an applicant chooses to measure airborne distance or time, at least six tests covering the landing weight range are required for each airplane configuration for which certification is desired. These tests should meet the following criteria:

(i) A stabilized approach, targeting a glideslope of -3 degrees and an indicated airspeed of $V_{REF}$, should be maintained for a sufficient time prior to reaching a height of 50 ft. above the landing surface to simulate a continuous approach at this speed. During this time, there should be no appreciable change in the power, attitude, or rate of descent. The average glideslope of all landings used to show compliance should not be steeper than -3 degrees.

(ii) Below 50 ft., there should be no nose depression by use of the longitudinal control and no change in configuration, except for reduction in power.

(iii) The target rate of descent at touchdown should not exceed 6 ft. per second. Target values cannot be achieved precisely; however, the average touchdown rate of descent should not exceed 6 ft. per second.

(3) If the applicant conducts enough tests to allow a parametric analysis which establishes with sufficient confidence the relationship between airborne distance (or time) as a function of the rates of descent at 50 ft. and touchdown, the Part 25 airborne distances may be based on an approach angle of -3.5 degrees and a touchdown sink rate of 8 ft. per second (see paragraph g for a sample of this analysis method).

(i) The air distance or air time established by this method may not be less than 90 percent of the lowest demonstrated value obtained using the target values for approach angle and touchdown sink rate specified in paragraph (ii) below. However, test data with approach angles steeper than -3.5 degrees and touchdown sink rates greater than 8 ft. per second may not be used to satisfy this requirement.

(ii) In order to determine the parametric relationships, it is recommended that test targets should span approach angles from -2.5 degrees to at least -3 degrees and sink rates at touchdown from 2-6 ft. per second. Target speed for all tests should be $V_{REF}$.

(iii) If an acceptable method of analysis is developed by an applicant to statistically establish a satisfactory confidence level for the resulting parametric relationships, then 12 tests, in each aerodynamic configuration for which certification is desired, will be sufficient. More tests will be necessary if the distribution of the data does not give sufficient confidence in the parametric correlation. Past experience has shown that a total of 40 landings would establish a satisfactory confidence level without further analysis. Autolands may be included in the analysis but should not comprise more than half of the data points. If it is apparent that configuration is not a significant variable, all data may be included in a single parametric analysis.

(iv) If new tests are necessary to substantiate performance to a weight higher than that permitted by the extrapolation limits of § 25.21(d), two landings per configuration will be required for each 5 percent increase in landing weight, with a maximum total requirement of six landings. These may be merged with previous certification tests for parametric analysis, whether the previous certification was conducted by this method or not.

(v) In calculating the AFM landing distances, the speed loss from 50 ft. to touchdown, as a percentage of $V_{REF}$, may be assumed using the conditions of paragraph (3) above.

(4) Whichever method is chosen to establish airborne distances, satisfactory flight characteristics must be demonstrated in the flare maneuver with the speed at 50 ft. of $V_{REF}$-5 knots, the application of longitudinal control to initiate flare may be at any point below 50 ft., and the touchdown speed should be at least 5 knots less than the touchdown speed used to establish the landing distance. The rate of descent at touchdown should not be greater than 6 ft. per second. Power should not be increased below the 50 ft. point in order to facilitate the flare. This demonstration must be performed at both maximum landing weight and at near minimum landing weight.

c. Procedures for Determination of the Transition and Stopping Distance.

(1) The transition distance extends from the initial touchdown point to the point where all approved deceleration devices are operative. The stopping distance extends from the end of transition to the point where the airplane is stopped. The two phases may be combined if the applicant prefers this method of analysis.

(2) If sufficient data are not available, there should be a minimum of six landings in the primary landing configuration. Experience has shown that if sufficient data are available for the airplane model to account for variation of braking performance with weight, lift, drag, ground speed, torque limit, etc., at least two test runs are necessary for each configuration when correlation for multiple configurations is being shown.

(3) A series of at least six measured landing tests covering the landing weight range should be conducted on the same set of wheels, tires, and brakes in order to substantiate that excessive wear of wheel brakes and tires is not produced in accordance with the provisions of § 25.125(b). The landing tests should be conducted with the normal operating brake pressures for which the applicant desires approval. The main gear tire pressure should be set to not less than the maximum pressure desired for certification corresponding to the specific test weight. Longitudinal control and brake application procedures must be such that they can be consistently applied in a manner that permits the airplane to be de-rotated at a controlled rate to preclude an excessive nose gear touchdown rate and so that the requirements of §§ 25.125(a)(4) and (5) are met. Certification practice has not allowed manually applied brakes before all main gear wheels are firmly on the ground.

(4) Airplane operating procedures appropriate for determination of landing distance must be described in the performance section of the AFM.

d. Landing on Unimproved Runways.

(1) Landing distances on surfaces other than paved hard surfaces require special considerations. An abbreviated series of test measurements is acceptable provided normal hard surface performance data has already been obtained. These surfaces are usually firm sod, dirt, or gravel runways. There should be some confidence that the footprint area and tire pressures are compatible with the surface to be operated from.

(2) The following should be considered a minimum:

(i) Define runway surface material and condition.

(ii) Define bearing strength of the proposed runway.

(iii) Measure landing ground roll using appropriate procedures. Four test runs are a minimum.

(iv) Evaluate ground handling characteristics.

(v) Evaluate the effect of foreign object damage and ingestion on safety of the proposed operation.

(vi) The need for any special safety devices such as deflector shields shall be evaluated.

(vii) Evaluate, if requested, the procedures for use of thrust reversers and the effect on airplane safety.

(viii) Establish any needed procedures and operating limitations. The heaviest weight demonstrated will constitute a landing weight limitation.

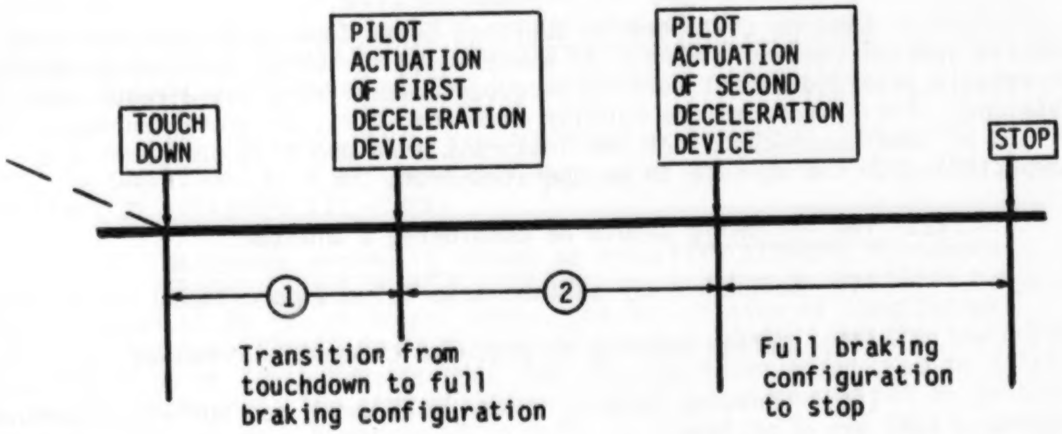
e. Instrumentation and Data. Instrumentation should include a means to record the airplane's glide path relative to the ground and the ground roll against time in a manner to determine the horizontal and vertical distance time histories. The appropriate data to permit analysis of these time histories should also be recorded.

f. Airplane Flight Manual Landing Distances.

(1) As a minimum the AFM must include data for standard temperature and zero runway gradient showing the variation of landing distance with weight (up to maximum takeoff), altitude, and wind. If the airplane is intended for operation under Part 121 of the FAR, the distances presented should include the operational field length factors for both dry and wet runways required by § 121.195.

(2) In deriving the scheduled distances, the time delays shown below should be assumed.

FIGURE 19-1. LANDING TIME DELAYS


TOUCH DOWN
PILOT ACTUATION OF FIRST DECELERATION DEVICE
PILOT ACTUATION OF SECOND DECELERATION DEVICE
STOP
①
②
Transition from touchdown to full braking configuration
Full braking configuration to stop

(i) ① This segment represents the flight test measured average time from touchdown to pilot actuation of the first deceleration device. For AFM data expansion, use the longer of 1 second or the test time.

(ii) ② This segment represents the flight test measured average test time from pilot actuation of the first deceleration device to pilot actuation of the second deceleration device. For AFM data expansion, see item ① above.

(iii) Step ② is repeated until pilot actuation of all deceleration devices has been completed and the airplane is in the full braking configuration.

(3) For approved automatic deceleration devices (e.g., autobrakes or auto-spoilers, etc.) for which performance credit is sought for AFM data expansion, established times determined during certification testing may be used without the application of the 1-second minimum time delay required in the appropriate segment above.

(4) It has been considered acceptable to expand the airborne portion of the landing distance in terms of a fixed airborne time, independent of airplane weight or approach speed.

(5) Assumptions to be made in assessing the effect of wind on landing distance are discussed in paragraph 3 of this AC.

g. Parametric Analysis Data Reduction. The following is an acceptable method of converting the test data to a mathematical model for the parametric analysis method of air distance described in paragraph b(3).

Test Data for Each Test Point:

$R/S_{50}$ = Rate of sink at 50 ft. above landing surface, Ft/Sec
$R/S_{TD}$ = Rate of sink at touchdown, Ft/Sec
$V_{50}$ = True airspeed at 50 ft. above landing surface, Ft/Sec
$V_{TD}$ = True airspeed at touchdown, Ft/Sec
$t$ = Air time 50 ft. to touchdown, Sec

The multiple linear regression analysis as outlined below is used to solve for the constant of the two independent variable equation:

$$50/t = a+b(R/S_{50})+(c)(R/S_{TD})$$

To maintain the same units for all variables, the dependent variable is chosen as 50/t.

The test values of all the test points, 1 through n, are processed as follows, where n equals the number of test points:

$$R1 = \sum_1^n R/S_{50}$$

$$R2 = \sum_1^n (R/S_{50})^2$$

$$R3 = \sum_1^n R/S_{TD}$$

$$R4 = \sum_1^n (R/S_{TD})^2$$

$$R5 = \sum_1^n (R/S_{50})(R/S_{TD})$$

$$R6 = \sum_1^n (50/t)$$

$$R7 = \sum_1^n (R/S_{50})(50/t)$$

$$R8 = \sum_1^n (R/S_{TD})(50/t)$$

$$R9 = (n)(R2)-(R1)^2$$

$$R10 = (n)(R8)-(R3)(R6)$$

$$R11 = (n)(R5)-(R1)(R3)$$

$$R12 = (n)(R7)-(R1)(R6)$$

$$R13 = (n)(R4)-(R3)^2$$

$$c = ((R9)(R10)-(R11)(R12))/((R9)(R13)-(R11)^2)$$

$$b = ((R12)-(c)(R11))/R9$$

$$a = ((R6)-(b)(R1)-(c)(R3))/n$$

In the same manner, determine the values of the constants, a, b, and c, in an equation for speed reduction between 50 ft. and touchdown by replacing 50/t with $(V_{50}/V_{TD})$ for each test run.

After determining the values of the constants, the two equations are used to calculate the time from 50 ft. to touchdown and $V_{50}/V_{TD}$ for the desired conditions of 3.5 degrees flight path and $R/S_{TD}$ = 8ft/Sec. The $R/S_{50}$ is calculated from the approach path and $V_{50}$.

After $V_{TD}$ is determined, the air distance may be determined for average speed and t.

Example:

Test Data:

| Run | $R/S_{50}$ | $R/S_{TD}$ | $V_{50}$ | $V_{TD}$ | t |
|---|---|---|---|---|---|
| 1 | 13.4 | 6.1 | 219 | 214 | 5.6 |
| 2 | 10.9 | 1.8 | 223 | 218 | 8.5 |
| 3 | 7.9 | 5.8 | 209 | 201 | 7.4 |
| 4 | 8.3 | 2.3 | 213 | 206 | 9.6 |
| 5 | 9.8 | 4.1 | 218 | 212 | 7.5 |

Results:

$50/t = 1.0432+.3647\ R/S_{50}+.4917\ R/S_{TD}$

$V_{50}/V_{TD} = 1.05508-.003198\ R/S_{50}+.001684\ R/S_{TD}$

For conditions of $V_{50} = 220$, flight path = 3.5 degrees, $R/S_{TD} = 8.0$ the resultants are:

$R/S_{50} = 13.43$

$t = 5.063$ sec.

$V_{50}/V_{TD} = 1.0256$

Air Distance = 1100 ft.

## Section 3. CONTROLLABILITY AND MANEUVERABILITY

### 20. GENERAL - § 25.143.

a. Explanation. The purpose of § 25.143 is to verify that any operational maneuvers conducted within the operational envelope can be accomplished smoothly with average piloting skill and without exceeding any airplane structural limits. Control forces should not be so high that the pilot cannot safely maneuver the airplane. Also, the forces should not be so light it would take exceptional skill to maneuver the airplane without overstressing it or losing control. The airplane response to any control input should be predictable to the pilot.

b. The applicable regulation is § 25.143.

c. Procedures. Compliance with § 25.143 is primarily a qualitative determination by the pilot during the course of the flight test program. The control forces required and airplane response should be evaluated during changes from one flight condition to another and during maneuvering flight. The forces required should be compatible for each flight condition evaluated. For example,during an approach for landing, the forces should be light and the airplane responsive in order that adjustments in the flight path can be accomplished with a minimum of workload. In cruise flight, forces and airplane response should be such that inadvertent control input does not result in exceeding limits or in undesirable maneuvers. Longitudinal control forces should be evaluated during accelerated flight to ensure a positive stick force with increasing normal acceleration. Forces should be heavy enough at the limit load factor to prevent inadvertent excursions beyond design limit. Sudden engine failures should be investigated during any flight condition or in any configuration considered critical, if not covered by another Section of Part 25. Control forces considered excessive should be measured to show compliance with § 25.143(c), "strength of pilots" limits. Allowance should be made for delays in the initiation of recovery action appropriate to the situation.

### 21. LONGITUDINAL CONTROL - § 25.145

a. Explanation.

(1) Section 25.145(a) requires that there be adequate longitudinal control to promptly pitch the airplane nose down from, at, or near the stall to return to the original trim speed. The intent is to insure sufficient pitch control if inadvertently slowed to the point of stall.

(2) Section 25.145(b) requires changes to be made in flap position, power, and speed without undue effort when retrimming is not practical. The purpose is to insure that any of these changes are possible assuming that the pilot finds it necessary to devote at least one hand to the initiation of the desired operation without being overpowered by the primary airplane controls. The objective is that no excessive change in trim will result from the application or removal of power or the extension or retraction of wing flaps. Compliance with its terms also requires that the relation of control force to speed be such that reasonable changes in speed may be made without encountering very high control forces.

(3) Section 25.145(c) is concerned with the eventuality of going around during an approach for landing in which event it is desirable to be able to retract the wing flaps and leading edge slats, if applicable, quickly at such a rate that there will be no loss of altitude if power is applied simultaneously with the initiation of flap/slat retraction. The design feature involved in this requirement is the rate of flap/slat retraction. Several changes to § 25.145(c) were made as a result of Amendment 25-23, which became effective May 8, 1970.

(i) The use of maximum continuous power was changed to takeoff power because there is no need to reserve additional power (thrust) between maximum continuous power and takeoff power for contingencies since compliance at critical altitudes and weights is required. Further, takeoff power from a controllability standpoint could be more critical (i.e. pitch up). Some airplanes have had to limit their go-around thrust at certain weights because of this condition. The critical engine operating conditions within the approved airplane operating envelope must also be considered.

(ii) Partial flap retraction to a gated position (design feature to prevent inadvertent operation beyond this position) is permitted. The gate design requirements are in the rule.

(iii) The initial speed was changed from $1.1V_{S1}$ to a speed of $1.2V_{S1}$ for turbojet airplanes, which is intended to assure that the minimum inflight go-around speed is related to realistic landing touchdown speeds.

b. The applicable regulations are §§ 25.145(a),(b), and (c) of the FAR.

c. Procedures. The following test procedures outline an acceptable means for demonstrating compliance with § 25.145. These tests may be conducted at an optional altitude in accordance with § 25.21(c). Where applicable, the conditions should be maintained on the engines throughout the maneuver.

(1) Longitudinal control recovery, § 25.145(a):

(i) Configuration:

(A) Maximum weight or a lighter weight if considered more critical.

(B) Aft c.g. position.

(C) Landing gear extended.

(D) Wing flaps retracted and extended to the maximum landing position.

(E) Engine power at idle and maximum continuous.

(ii) Test procedure: The airplane should be trimmed at the speed for each configuration as prescribed in § 25.103(b)(1). The nose should be pitched downward from any speed between V trim and the stall. In past programs the most critical point has been at the stall when in stall buffet. The rate of speed increase should be adequate to promptly return to the trim point. Data from the stall characteristics test could be used to evaluate this condition at the stall.

(2) Longitudinal control, flap extension, § 25.145(b)(1).

(i) Configuration:

(A) Maximum landing weight.

(B) Critical c.g. position.

(C) Wing flaps retracted.

(D) Landing gear extended.

(E) Engine power at flight idle.

(ii) Test procedure: The airplane should be trimmed at a speed of $1.4V_S$. The flaps should be extended to the maximum landing position as rapidly as possible while maintaining approximately $1.4V_S$ for the flap position existing at each instant throughout the maneuver. The control forces should not exceed 50 lbs. (the maximum temporary forces that can be applied readily by one hand) throughout the maneuver without changing the trim control.

(3) Longitudinal control, flap retraction, §§ 25.145(b)(2) & (3).

(i) Configuration:

(A) Maximum landing weight.

(B) Critical c.g. position.

(C) Wing flaps extended to maximum landing position.

(D) Landing gear extended.

(E) Engine power at flight idle and takeoff.

(ii) With the airplane trimmed at $1.4V_S$, the flaps should be retracted to the full up position while maintaining approximately $1.4V_S$ for the flap position existing at each instant throughout the maneuver. The longitudinal control force should not exceed 50 lbs. throughout the maneuver without changing the trim control.

(4) Longitudinal control, power application, § 25.145(b)(4) & (5).

(i) Configuration:

(A) Maximum landing weight.

(B) Critical c.g. position.

(C) Wing flaps retracted and extended to the maximum landing position.

(D) Landing gear extended.

(E) Engine power at flight idle.

(ii) Test procedure: The airplane should be trimmed at a speed of $1.4V_S$. Takeoff power should be applied quickly while maintaining the speed of $1.4V_S$. The longitudinal control force should not exceed 50 lbs. throughout the maneuver without changing the trim control.

(5) Longitudinal control, airspeed variation, § 25.145(b)(6).

(i) Configuration:

(A) Maximum landing weight.

(B) Most forward c.g. position.

(C) Wing flaps extended to the maximum landing position.

(D) Landing gear extended.

(E) Engine power at flight idle.

(ii) Test Procedure: The airplane should be trimmed at a speed of $1.4V_S$. The speed should then be reduced to $1.1V_S$ and then increased to $1.7V_S$, or the flap placard speed, $V_{FE}$, whichever is lower. The longitudinal control force should not be greater than 50 lbs. Data from the static longitudinal stability tests in the landing configuration at forward c.g., § 25.175(d), may be used to show compliance with this requirement.

(6) Longitudinal control, flap retraction and power application, § 25.145(c).

(i) Configuration:

(A) Critical combinations of maximum landing weights and altitudes.

(B) Critical c.g. position.

(C) Wing flaps extended to the maximum landing position and gated position, if applicable.

(D) Landing gear extended.

(E) Engine power for level flight at a speed of $1.1V_S$ for propeller driven airplanes, or $1.2V_S$ for turbojet powered airplanes.

(ii) Test procedure: With the airplane stable in level flight at a speed of $1.1V_S$ for propeller driven airplanes, or $1.2V_S$ for turbojet powered airplanes, the flaps should be retracted to the full up position, or next gated position, while simultaneously applying inflight takeoff power. The power used should be critical with respect to controllability or performance. It should be possible to prevent any loss of altitude without exceptional piloting skill. Trimming throughout this maneuver is permissible. If gates are provided, this test should be conducted from the maximum landing flap position to the first gate, from gate to gate, and from the last gate to the fully retracted position. The gate design requirement is specified in the rule. The landing gear should remain extended throughout the test.

## 22. DIRECTIONAL AND LATERAL CONTROL - § 25.147.

### a. Explanation.

(1) Sections 25.147(a) and (b) are intended to be investigated for dangerous characteristics such as rudder lock or loss of directional control with one or two critical engines inoperative. Sudden heading changes of up to 15 degrees are required unless the rudder force limit of 150 lbs. (180 lbs. prior to Amendment 25-42) is reached. If the rudder reaches full travel without attaining 150 lbs. force limit or a 15-degree heading change, satisfactory controllability must be demonstrated with this configuration for expected service operations. After full rudder is reached, heading changes using lateral control are permissible provided that no more than a 5-degree bank angle is required.

(2) Sections 25.147(a) and (b) are written to show an airplane will still be under control if yawed suddenly toward and against inoperative engine(s). Paragraphs (c) and (d) require an airplane to be easily controllable with critical inoperative engine(s). Roll response, § 25.147(e), should be satisfactory for takeoff, approach, landing, and high speed configurations. Any permissible configuration which could affect roll response should be evaluated.

### b. Procedures.

(1) Directional Control - General, § 25.147(a).

(i) Configuration:

(A) Maximum landing weight.

(B) Most aft c.g. position.

(C) Wing flaps extended to the approach position.

(D) Landing gear retracted.

(E) Yaw SAS on, and off if applicable.

(F) Operating engine(s) at the power for level flight at $1.4V_S$, but not more than maximum continuous power.

(G) Inoperative engine that would be most critical for controllability, with propeller feathered, if applicable.

(ii) Test Procedure: The airplane should be trimmed in level flight at the most critical altitude in accordance with § 25.21(c). Reasonably sudden changes in heading to the left and right, using ailerons to maintain approximately wings level flight, should be made demonstrating a change up to 15 degrees or at which 150 lbs. rudder force is required. The airplane should be controllable and free from any hazardous characteristics during this maneuver.

(2) Directional Control - Four or More Engines, § 25.147(b).

(i) Configuration:

(A) Maximum landing weight.

(B) Most forward c.g. position.

(C) Wing flaps in the most favorable climb position (normally retracted).

(D) Landing gear retracted.

(E) Yaw SAS on, and off if applicable.

(F) Operating engines at the power required for level flight at $1.4V_{S1}$, but not more than maximum continuous power.

(G) Two inoperative engines that would be more critical for controllability with (if applicable) propellers feathered.

(ii) Test Procedure: The procedure outlined in subparagraph b(1)(ii) above is applicable to this test.

(3) Lateral Control - General, § 25.147(c).

(i) Configuration:

(A) Maximum takeoff weight.

(B) Most aft c.g. position.

(C) Wing flaps in the most favorable climb position.

(D) Landing gear retracted and extended.

(E) Yaw SAS on, and off if applicable.

(F) Operating engine(s) at maximum continuous power.

(G) The inoperative engine that would be most critical for controllability, with the propeller feathered, if applicable.

(ii) Test Procedure: With the airplane trimmed at $1.4V_S$, turns with a bank angle of 20 degrees should be demonstrated with and against the inoperative engine from a steady climb at $1.4V_{S1}$. It should not take exceptional piloting skill to make smooth, predictable turns.

(4) Lateral Control - Four or More Engines, § 25.147(d).

(i) Configuration:

(A) Maximum takeoff weight.

(B) Most aft c.g. position.

(C) Wing flaps in the most favorable climb position.

(D) Landing gear retracted and extended.

(E) Yaw SAS on, and off if applicable.

(F) Operating engines at maximum continuous power.

(G) Two inoperative engines most critical for controllability, with propellers feathered, if applicable.

(ii) Test Procedure: The procedure outlined in subparagraph b(3)(ii) is applicable to this test.

(5) Lateral Control - All Engines Operating, § 25.147(e).

(i) Configuration: All configurations within the flight envelope for normal operation.

(ii) Test Procedure: This is primarily a qualitative evaluation which should be conducted throughout the test program. Roll performance should be investigated throughout the flight envelope, including speeds to $V_{FC}/M_{FC}$, to ensure adequate peak roll rates for safety, considering the flight condition, without excessive control force or travel. Roll response during sideslips expected in service should provide enough maneuvering capabilities adequate to recover from such conditions. Approach and landing configurations should be carefully evaluated to ensure adequate control to compensate for gusts and wake turbulence while in close proximity to the ground.

## 23. MINIMUM CONTROL SPEED - § 25.149.

a. Explanation. Section 25.149 defines requirements for minimum control speeds during takeoff climb ($V_{MC}$), during takeoff ground roll ($V_{MCG}$), and during landing approach ($V_{MCL}$). The $V_{MC}$ (commonly referred to as $V_{MCA}$) requirements are specified in §§ 25.149(a), (b), (c) and (d); the $V_{MCG}$ requirements are described in § 25.149(e); and the $V_{MCL}$ requirements are covered in §§ 25.149(f), (g) and (h). Section 25.149(a) states that the method used to simulate critical engine failure must represent the most critical mode of powerplant failure with respect to controllability in service. That is, the thrust loss from the inoperative engine must be at the rate that would occur if an engine suddenly became inoperative in service. Prior to Amendment 25-42 to § 25.149, the regulation required that rudder control forces must not exceed 180 lbs. Amendment 25-42 limits rudder control forces to 150 lbs. The relationship between $V_{EF}$, $V_1$, and $V_{MCG}$, including the requirements applicable prior to Amendment 25-42, is discussed in paragraph 10, Takeoff and Takeoff Speeds, and paragraph 11, Accelerate-Stop Distance.

b. Procedures.

(1) Minimum Control Speeds - Air ($V_{MCA}$).

(i) To comply with the $V_{MCA}$ requirements, the following two conditions must be satisfied: (Separate tests are usually conducted to show compliance with these two requirements.)

(A) The dynamic condition in which control is maintained without exceeding a heading change of 20 degrees.

(B) The stabilized (static) condition where constant heading is maintained without exceeding a 5-degree bank angle.

(ii) Static Test Procedure and Required Data. After establishing the critical inoperative engine, the tests for establishing the minimum control speed may be conducted. Using the configuration specified in § 25.149 with the critical engine inoperative, the remaining engine(s) will be adjusted to maximum takeoff power and/or thrust; the airspeed will be decreased until one of the limiting factors specified in §§ 25.149(b), (c) or (d) is experienced. For airplanes with more than two engines, the inboard engine(s) may be throttled, provided the appropriate yawing moment coefficient ($C_N$) is maintained. If the maximum power and/or thrust within the approved airplane operating envelope was maintained to the minimum test speed, this speed may be used as the $V_{MCA}$ for the airplane. If, at the option of the applicant, $V_{MCA}$ is to vary with altitude and temperature, the minimum test speed and corresponding thrust may be reduced to an equivalent $C_N$. From this $C_N$, $V_{MCA}$ may be calculated to vary with takeoff thrust. If maximum takeoff thrust could not be achieved during this test, the $C_N$ can be used to calculate the $V_{MCA}$ for maximum takeoff thrust. It has been acceptable to extend the thrust 5 percent beyond the test thrust. If $V_{MCA}$ is near or less than $V_S$ for the test airplane, consideration may be given to conducting the test at a more extended flap position. It should be noted, however, that a more extended flap position may produce unconservative results. In the event $V_{MCA}$ is less than stall speed at all usable operational gross weights, demonstration that shows compliance with the $V_{MCA}$ requirements may be shown as follows:

(A) Conduct static $V_{MCA}$ tests using partial rudder deflections to achieve a variation in $C_N$ with rudder deflection.

(B) Plot the asymmetric thrust yawing moment ($C_N$) versus control surface deflection (lateral and directional). These plots should be faired and then extrapolated to full control surface deflections. Plot $C_N$ versus rudder pedal force. This plot should be faired to 150 lbs. (180 lbs. prior to Amendment 25-42). Whichever condition of the three is most limiting determines the maximum $C_N$ from which $V_{MCA}$ can be calculated.

(C) The extrapolation should be limited to 5 percent of the yawing moment coefficient unless a rigorous analysis is made to account for all of the stability and control terms.

(D) Compute the stalling speed ($V_S$) at the airplane Operational Weight Empty (OWE) for the maximum takeoff flap position and compute $V_{MCA}$ from $C_N$ using the maximum asymmetric takeoff thrust. If the computed $V_{MCA}$ is less than $V_S$, then the airplane is stall limited and $V_{MCA}$ is not a factor.

(iii) Dynamic Test Procedure and Required Data. In addition to the static test procedure, dynamic demonstrations should be made to provide adequate proof that the speed(s) determined also meet the dynamic requirements. The dynamic demonstration is conducted by applying the maximum rated power and/or thrust to all engines and suddenly cutting the critical engine. It should be possible to recover to a constant heading without exceeding the requirements of § 25.149(d). If the thrust/weight for the dynamic demonstration produces an extreme nose-high attitude, normally more than 20 degrees, another method should be used such as conducting dynamic demonstrations using a minimum required rudder and aileron control at reduced thrust and comparing control deflection and force required between the dynamic demonstration and static demonstration at several reduced thrust conditions.

(iv) If $V_{MCA}$ has been shown to be less than $V_S$ by the static method, the dynamic demonstration may be conducted at speeds such as $1.1V_S$ and evaluated in accordance with paragraph (iii) above.

(v) Normally, $V_{MCA}$ and $V_{MCG}$ will be determined by rendering the engine inoperative and allowing the propeller to autofeather; however, on some airplanes a more critical drag condition can be produced during a partial power condition. Some engine propeller combinations might be subject to this type of failure. One example is some turbopropeller installations can have a fuel control failure that causes the engine to go to flight idle, resulting in a higher asymmetric drag than that obtained from an inoperative engine. In such a case, the test must be conducted in the most critical condition.

(vi) There may be some difference between right and left engine inoperative $V_{MCA}$ due to propeller slip stream rotation reducing rudder effectiveness to maintain the airplane on its original heading. The critical engine should be determined and the $V_{MCA}$ for that configuration should be used.

(vii) $V_{MCA}$ and $V_{MCG}$ should be based on the maximum net thrust reasonably expected for a production engine. These speeds should not be based on specification thrust since this thrust represents the minimum thrust as guaranteed by the engine manufacturer, and the resulting speeds could be too slow. The thrust used for scheduled $V_{MCA}$ and $V_{MCG}$ speeds should represent the high side of the tolerance band and may be determined by analysis instead of tests.

(2) Minimum Control Speed - Ground ($V_{MCG}$) - § 25.149(e).

(i) It must be demonstrated that, when the critical engine is suddenly made inoperative at $V_{MCG}$ during the takeoff ground roll, the airplane is safely controllable to continue the takeoff. During the demonstration, the airplane must not deviate more than 30 ft. (25 ft. prior to Amendment 25-42) from the pre-engine-cut projected ground track. The critical engine is determined by the methods as described above under § 25.149(c).

(ii) Tests may be conducted by abruptly retarding the engine to idle to establish the target $V_{MCG}$. At least one fuel cut should be made at each maximum asymmetric thrust level desired to be certificated to investigate the more rapid thrust decay associated with this type of engine failure. At the applicant's option, in crosswind conditions, the runs may be made on reciprocal headings or an analytical correction may be applied to determine the zero crosswind value of $V_{MCG}$.

(iii) During determination of $V_{MCG}$, engine failure recognition should be by pilot sensation or outside reference only, unless an engine failure warning device is installed.

(iv) Control of the airplane should be accomplished by use of the rudder only. All other controls, like ailerons and spoilers, should only be used to correct any alterations in the airplane attitude and to maintain a wings level condition. Use of those controls to supplement the rudder effectiveness should not be allowed.

(v) The $V_{MCG}$ should be considered at the heaviest weight where $V_{MCG}$ may impact the AFM $V_1$ schedule.

(vi) The test should be conducted at aft c.g. and with the nose wheel free to caster, to minimize the stabilizing effect of the nose gear.

(vii) For airplanes with certification basis prior to Amendment 25-42, $V_{MCG}$ values may be demonstrated with nose wheel rudder pedal steering operative for dispatch on wet runways. The test should be conducted on an actual wet runway. The test(s) should include engine failure at or near a minimum $V_{EF}$ associated with minimum $V_R$ to demonstrate adequate controllability during during rotation, liftoff, and the initial climbout. The $V_{MCG}$ values obtained by this method are applicable for wet or dry runways only, not for icy runways.

(3) Minimum Control Speed During Landing Approach $V_{MCL}$ - § 25.149(f).

(i) This section is intended to cover the controllability aspects of an engine failure during landing approach. Section 25.149(f) requires that minimum control speeds during landing approach with all engines operating at maximum available inflight power or thrust be determined when the critical engine is suddenly made inoperative. $V_{MCL}$ is defined as that speed where it is possible to recover control of the airplane with the engine still inoperative and maintain straight flight either with zero yaw or, at the option of the applicant, with an angle of bank of not more than 5 degrees. $V_{MCL}$ is the minimum control speed for the situation where an engine fails after power or thrust has been increased to make a go-around from an approach with all engines operating.

(ii) The initial power condition at the time of engine failure should be the maximum available inflight takeoff thrust. The procedures given in paragraph (1) for $V_{MCA}$ may be applied in determining $V_{MCL}$, except flap settings and trim settings should be appropriate to the maximum approach flap used to show compliance with § 25.121(d).

(4) Minimum Control Speed with Two Inoperative Engines During Landing Approach ($V_{MCL-2}$) - § 25.149(g).

(i) For airplanes with three or more engines, $V_{MCL-2}$ is the minimum speed for maintaining safe control during the power or thrust changes that are likely to be made following the failure of a second engine during an approach initiated with one engine inoperative.

(ii) This test should be conducted in the most critical one-engine-inoperative approach or landing configuration (from the AFM), usually the minimum flap deflection. Two demonstrations are required to determine $V_{MCL-2}$.

(A) With power on the operating engines set to maintain a -3 degree glideslope, with one critical engine inoperative, the second critical engine is made inoperative and the remaining operating engine(s) advanced to maximum available inflight takeoff power. The $V_{MCL-2}$ speed is established by the procedures presented in paragraphs (1)(i) and (ii) for $V_{MCA}$.

(B) With power on the operating engines set to maintain a -3 degree glideslope, with one critical engine inoperative:

(1) Set the airspeed at the value determined above in step (A) and, with zero bank angle, maintain a constant heading using trim to reduce the control force to zero. If full trim is insufficient to reduce the control force to zero, full trim should be used plus control deflection as required; and

(2) Make the second critical engine inoperative and retard the remaining operating engine(s) to minimum available power without changing the directional trim. The $V_{MCL-2}$ determined in paragraph (A) is acceptable if constant heading can be maintained without exceeding a 5-degree bank angle and the limiting conditions of § 25.149(h).

## Section 4. TRIM

24. [RESERVED]

## Section 5. STABILITY

25. [RESERVED]

### 26. STATIC LONGITUDINAL STABILITY AND DEMONSTRATION OF STATIC LONGITUDINAL STABILITY - §§ 25.173 AND 25.175.

a. Explanation.

(1) Section 25.173 - Static Longitudinal Stability.

(i) Compliance with the general requirements of § 25.173 are determined from a demonstration of static longitudinal stability under the conditions specified in § 25.175.

(ii) The requirement is to have a pull force to obtain and maintain speeds lower than trim speed and a push force to obtain and maintain speeds higher than trim speed. There may be no force reversal at any speed that can be obtained, except lower than the minimum for steady, unstalled flight or higher than the landing gear or wing flap operating limit speed or $V_{FC}/M_{FC}$, whichever is appropriate for the test configuration. The required trim speeds are specified in § 25.175.

(iii) When the control force is slowly released from any speed within the required test speed range, the airspeed must return to within 10 percent of the original trim speed in the climb, approach, and landing conditions, and return to within 7.5 percent of the trim speed in the cruising condition specified in § 25.175 (free return).

(iv) The average gradient of the stick force versus speed curves for each test configuration may not be less than one pound for each 6 knots for the appropriate speed ranges specified in § 25.175. Therefore, after each curve is drawn, draw a straight line from the intersection of the curve and the required maximum speed to the trim point. Then draw a straight line from the intersection of the curve and the required minimum speed to the trim point. The slope of these lines must be at least one pound for each 6 knots. The local slope of the curve must remain stable for this range.

Note: Due to different design features of individual airplanes, there may be cases where the local slope gradient deviates somewhat from that specified by § 25.173. When this occurs, an investigation should be performed to determine if a finding of equivalent safety can be made based on pilot evaluation.

(2) Section 25.175, Demonstration of Static Longitudinal Stability, specifically defines the flight conditions, airplane configurations, trim speed, test speed ranges, and thrust settings where demonstration is required.

b. Procedures.

(1) For the demonstration of static longitudinal stability, the airplane should be trimmed in smooth air at the conditions required by the regulation. Aft c.g. loadings are generally most critical. After obtaining

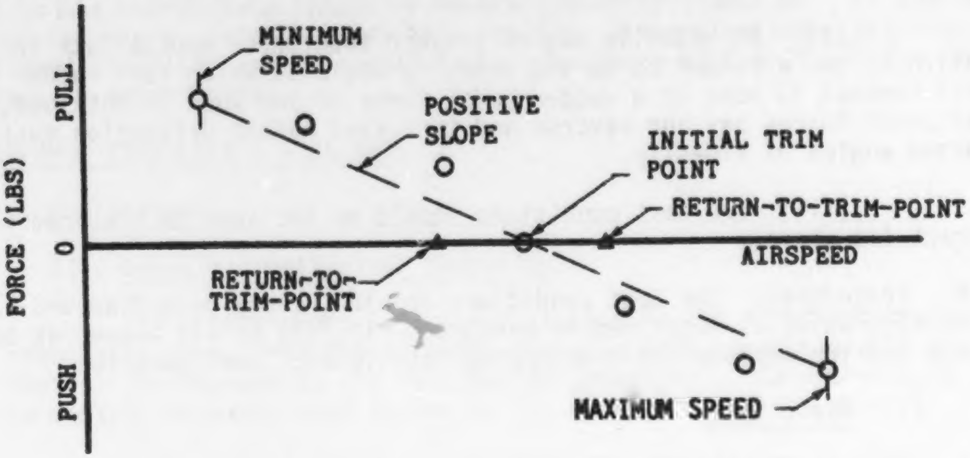
trim speed, apply a light pull force and stabilize at a slower speed. Continue this process in acceptable increments, depending on the speed spread being investigated, until reaching the minimum speed for steady, unstalled flight or the minimum required as appropriate for the configuration. A continuous pull force from the trim speed is required on each series of test points to eliminate hysteresis effects. At the end of the required speed range, the force should be gradually relaxed to allow the airplane to slowly return toward the trim speed and zero stick force. Depending on the amount of friction in the control system, the eventual speed at which the airplane stabilizes will normally be less than the original trim speed. The new speed, called the free return speed, must meet the requirements of § 25.173.

(2) Starting again at the trim speed, push forces should be gradually applied and gradually relaxed in the same manner as described in paragraph (1).

(3) The above techniques result in several problems in practice. One effect of changing airspeed is a change of altitude, with a corresponding change in Mach number and thrust or power output. Consequently, a reasonably small altitude band, limited to ±3,000 ft., should be used for the complete maneuver. If the altitude band is exceeded, regain the original trim altitude by changing the power setting and flap and gear position, but without changing the trim setting. Then continue the push or pull maneuver in the original configuration. Testing somewhat beyond the required speed limits in each direction assures that the resulting data at least extends to the required speed ranges. It will also be noted in testing that while holding force constant at each data point, the airspeed and instantaneous vertical speed vary in a cyclic manner. This is due to the long period (phugoid) oscillation. Care should be exercised in eventing the data point, since it may be biased by this phugoid oscillation. Averaging these oscillating speeds at each data point is an acceptable method of eliminating this effect. Extremely smooth air improves the quality of the test data with critical areas requiring the best of smooth air. In-bay and cross-bay wing fuel shift is another problem experienced in some airplanes. In-bay fuel shift occurs rapidly with pitch angle; therefore, consideration should be given to testing with fuel loadings that provide the maximum shift since it is generally destabilizing. Slower, cross-bay fuel shift, or burn from an aft tank, can influence the measured stability but usually only because of the time required to obtain the data points. This testing induced instability should be removed from the data before evaluation of the required slope.

(4) The resulting pilot longitudinal force test points should be plotted versus airspeed to show the positive stable gradient of static longitudinal stability. This plot should also show the initial trim point and the two return-to-trim points to evaluate the return-to-trim characteristics (see Figure 26-1).

FIGURE 26-1. STATIC LONGITUDINAL STABILITY



## 27. STATIC DIRECTIONAL AND LATERAL STABILITY - § 25.177.

a. Explanation.

(1) Static Directional Stability. Positive static directional stability is defined by § 25.177(a) as the tendency to recover from a skid with the rudder free. Positive static directional stability is required for any landing gear and flap position and symmetrical power condition at speeds from $1.2V_{S1}$ up to $V_{FE}$, $V_{LE}$, or $V_{FC}/M_{FC}$ as appropriate for the airplane configuration.

(2) Static Lateral Stability. Positive static lateral stability is defined by § 25.177(b) as the tendency to raise the low wing in a sideslip with the aileron controls free. Static lateral stability may not be negative in any landing gear and flap position and symmetrical power condition at speeds from $1.2V_{S1}$ to $V_{FE}$, $V_{LE}$, or $V_{MO}/M_{MO}$, as appropriate for the airplane configuration. At speeds from $V_{MO}/M_{MO}$ to $V_{FC}/M_{FC}$, negative static lateral stability is permissible providing the divergence is:

(i) Gradual,

(ii) Easily recognizable by the pilot, and

(iii) Easily controllable by the pilot.

(3) Steady Straight Sideslips.

(i) Section 25.177(c) requires, in steady straight sideslips to sideslip angles appropriate to the operation of the airplane, that the aileron and rudder control movements and forces be proportional to the angle of sideslip and must lie between limits necessary for safe operation. Experience has shown that 15 degrees is an appropriate angle for transport category airplanes.

(ii) At sideslip angles greater than those appropriate for operation of the airplane up to the sideslip angle at which full rudder or lateral control is used or a rudder pedal force of 180 lbs. is obtained, the rudder pedal forces may not reverse and increased rudder deflection must produce increased angles of sideslip.

(iii) The test conditions should be the same as required in paragraph (1) above.

b. Procedures. The test conditions should include each flap and landing gear configuration as described in paragraph (1), (2) or (3) above, at both low altitude and the maximum altitude appropriate to each configuration.

(1) Basic Test.

(i) Static Directional Stability. To check static directional stability with the airplane in the desired configuration and stabilized at the trim speed, the airplane is slowly yawed in both directions while maintaining the wings level with ailerons. When the rudder is released, the airplane should tend to return to straight flight.

(ii) Static Lateral Stability. To check lateral stability with a particular configuration and trim speed, conduct steady, straight sideslips at the trim speed by maintaining the airplane heading with rudder and banking with aileron. When the ailerons are released, with the rudder held fixed, the low wing should tend to return to level. Initial bank angle should be appropriate to type; however, it is recommended that it should not be less than 10 degrees. Roll control centering by the pilot should not be permitted during this evaluation.

(iii) Absence of Rudder Lock.

(A) Rudder lock is that condition where the rudder over-balances aerodynamically and deflects fully with no additional pilot input.

(B) To check for the absence of rudder lock with a particular configuration and trim speed, conduct steady, straight sideslips (unaccelerated forward slips) while maintaining a desired airplane track.

(C) Aileron and rudder control movements must remain in harmony and forces must increase in proportion with sideslip angle, up to the limits found necessary for safe operation. At sideslip angles greater than those appropriate for operation of the airplane up to the sideslip angle at which full rudder or lateral control is used or when a rudder pedal force of 180 lbs. is obtained, the rudder pedal forces may not reverse and increased rudder pedal deflection must produce increased angles of sideslip.

(2) Alternative Test. In lieu of conducting each of the qualitative tests described in paragraph (1), the applicant may obtain recorded quantitative data showing aileron and rudder force and position versus sideslip (left and right) to the appropriate limits in constant heading sideslips. If the force and position versus sideslip indicates positive dihedral effect, positive directional stability and no rudder lock, compliance with § 25.177 has been successfully demonstrated.

## 28. DYNAMIC STABILITY - § 25.181.

### a. Explanation.

(1) Dynamic Longitudinal Stability.

(i) The short period oscillation is the first oscillation the pilot sees after disturbing the airplane from its trim condition with the pitch control (as opposed to the long period (phugoid)). Care should be taken that the control movement used to excite the motion is not too abrupt.

(ii) Heavily damped means that the oscillation is damped within approximately two cycles after completion of initial input.

(iii) Short period oscillation must be heavily damped both with controls free and controls fixed.

(2) Dynamic Lateral-Directional Stability. The evaluation of the dynamic lateral-directional stability should include any combined lateral-directional oscillation ("Dutch Roll") occurring between stalling speed and maximum allowable speed appropriate to the airplane configuration. This oscillation must be positively damped with controls free, and must be controllable with normal use of the primary controls without requiring exceptional piloting skill.

### b. Procedures.

(1) Dynamic Longitudinal Stability.

(i) The test for longitudinal dynamic stability is accomplished by a rapid movement or pulse of the longitudinal control in a nose up and nose down direction at a rate and degree to obtain a short period pitch response from the airplane.

(ii) Dynamic longitudinal stability must be checked at a sufficient number of points in each configuration to assure compliance at all operational speeds.

(2) Dynamic Lateral-Directional Stability.

(i) A typical test for lateral-directional dynamic stability is accomplished by a rudder doublet input at a rate and amplitude which will excite the lateral-directional response ("Dutch Roll"). The frequency should be in phase with the airplane's oscillatory response.

(ii) Dynamic lateral-directional stability must be checked under all conditions and configurations. If critical, special emphasis should be placed on adverse wing fuel loading conditions.

(3) Airplanes Equipped with Stability Augmentation Systems (SAS). In the event the airplane is equipped with an SAS in order to comply with §§ 25.181(a) or (b), it must meet the requirements of §§ 25.671 and 25.672. If the airplane is equipped with more than one SAS and meets the requirements of §§ 25.671 and 25.672, it is the applicant's option to demonstrate compliance with § 25.181(a) or (b) with the SAS off.

## Section 6. STALLS

### 29. STALL TESTING.

a. The applicable Federal Aviation Regulations (FAR) are as follows:

| | |
|---|---|
| Section 25.21(c) | Proof of Compliance |
| Section 25.103 | Stalling Speed |
| Section 25.143 | Controllability and Maneuverability (General) |
| Section 25.201 | Stall Demonstration |
| Section 25.203 | Stall Characteristics |
| Section 25.205 | Stalls: Critical Engine Inoperative |
| Section 25.207 | Stall Warning |

b. Explanation.

(1) The purpose of stall testing is threefold:

(i) To define the minimum inflight airspeeds and how they vary with weight, altitude, and airplane configuration (stall speeds).

(ii) To demonstrate that handling qualities are adequate to allow a safe recovery from the highest angle-of-attack attainable in normal flight (stall characteristics).

(iii) To determine that there is adequate prestall warning (either aerodynamic or artificial) to allow the pilot time to recover from any probable high angle-of-attack condition without inadvertently stalling the airplane.

(2) During this testing, the angle-of-attack should be increased at least to the point where the following two conditions are satisfied:

(i) Attainment of an angle-of-attack measurably greater than that for maximum lift, except when the stall is defined by a stall prevention device (e.g., stick pusher).

(ii) Clear indication to the pilot through the inherent flight characteristics or stall prevention device (e.g., stick pusher) that the airplane is stalled.

(3) The airplane is considered to be fully stalled when any one or a combination of the below listed characteristics occurs to give the pilot a clear and distinctive indication that he should stop any further increase in angle of attack, at which time recovery should be initiated using normal techniques. The

stall speed is defined as the minimum speed reached during the maneuver, except for those airplanes which require stall prevention devices (see paragraph (v) below).

(i) The pitch control reaches the aft stop and no further increase in pitch attitude occurs when the control is held full aft for a short time before recovery is initiated.

(ii) An uncommanded, distinctive and easily recognizable nose down pitch that cannot be readily arrested.

(iii) A roll that cannot be readily arrested with normal use of lateral/directional control.

(iv) The airplane demonstrates an unmistakable, inherent aerodynamic warning of a magnitude and severity that is a strong and effective deterrent to further speed reduction. This deterrent level of aerodynamic warning (i.e., buffet) must be of a much greater magnitude than the initial buffet ordinarily associated with stall warning. An example is a large transport airplane which exhibits "deterrent buffet" with flaps up and is characterized by an intensity which inhibits reading cockpit instruments and would require a strong determined effort by the pilot to increase the angle-of-attack any further.

(v) The activation point of a stall prevention device which is a strong and effective deterrent to further speed reduction. If an artificial stall prevention system is used, stall speed may be defined as the minimum speed in the maneuver, provided stall characteristics are shown to be acceptable at an angle-of-attack at least 10 percent beyond the activation point of the stall prevention device. (See Figure 29-1.)

(4) It should be recognized that the point at which the airplane is considered stalled may vary, depending on the airplane configuration (flaps, gear, drag devices, center of gravity, and gross weight). In any case, the angle-of-attack must be increased until one or more of these characteristics is reached for all likely combinations of variables.

c. Stall Speeds.

(1) Background. Since many of the regulations pertaining to performance and handling qualities specify trim speeds and other variables which are functions of stall speeds, it is desirable to accomplish the stall speed testing early in the program, so the data are available for subsequent testing. Because of this interrelationship between the stall speeds and other critical performance parameters, it is essential that accurate measurement methods be used. Most standard airplane pitot-static systems have not been found to be acceptable for stall speed determination. These tests require the use of properly calibrated instruments and usually require a separate test airspeed system, such as a trailing bomb, a trailing cone, or an acceptable nose or wing boom.

(2) Configuration.

(i) Stall speeds should be determined for all aerodynamic configurations to be certificated for use in the takeoff, enroute, approach, and landing configurations.

(ii) The center of gravity positions to be used should be those which result in the highest stall speeds for each weight (forward c.g. in most cases).

(iii) Sufficient testing should be conducted to determine the effects of weight on stall speed. Altitude effects (compressibility, Reynolds Number) may also be considered if credit for variations in these parameters is sought by the applicant. If stall speeds are not to be defined as a function of altitude, then all stall speed testing should be conducted at a nominal altitude no lower than 1,500 ft. above the maximum approved takeoff and landing altitude. (See Figures 29-3 and 29-4.)

(3) Procedures.

(i) The airplane should be trimmed for hands-off flight at a speed 20 percent to 40 percent above the anticipated stall speed with the engines at idle and the airplane in the prescribed configuration for which the stall speed is being determined. Then, using only the primary longitudinal control, a constant deceleration (entry rate) is maintained until one of the previously defined points which define the stall is reached. Following the stall, engine thrust may be utilized, as desired, to expedite recovery.

(ii) A sufficient number of stalls (normally six) should be accomplished at each critical combination of weight, c.g., and external configuration, varying the entry rate from approximately 0.5 knots/second to 1.5 knots/second. The intent is to obtain enough data to define the stall speed at an entry rate of 1.0 knots/second. (See Figure 29-2.)

(iii) During the stall speed testing, the stall characteristics of the airplane must also satisfy the requirements of §§ 25.203(a) and (b).

(4) Thrust Effects on Stall Speed.

(i) Stall speeds are normally defined with the thrust levers at idle; however, it is necessary to verify by test or analysis that engine idle thrust does not affect stall speeds to an extent that they are appreciably lower than would be experienced at zero thrust. Negative thrust at the stall which slightly increases stall speeds is acceptable.

(ii) To determine whether thrust effects on stall speed are significant, at least three stalls should be conducted at one flap setting, with thrust set to approximately the value required to maintain level flight at $1.6V_S$ in the selected configuration.

(iii) These data may then be extrapolated to a zero thrust condition to eliminate the effects of idle thrust on stall speeds. (See Figure

29-5.) If the difference between idle thrust and zero thrust stall speed is 0.5 knots or less, the effect may be considered insignificant.

(iv) The effects of engine power on stall speeds for a turbopropeller airplane can be evaluated in a similar manner. Engine torque, engine r.p.m., and estimated propeller efficiency can be used to predict thrust. As an alternative, stalls may be conducted first at flight idle, and then repeated with all propellers in the feathered position. This comparison will directly identify the effects of idle power on stall speeds.

(5) Data Reduction and Presentation. The following is an example of how the data obtained during the stall speed testing may be reduced to standard conditions. Other methods have been found acceptable.

(i) Indicated airspeed from the flight test airspeed system is recorded throughout the stall, and these values are corrected to equivalent airspeed.

(ii) Stall entry rate is then defined as the slope of a straight line connecting stall speed and an airspeed 10 percent above the stall speed (See Figure 29-1.)

$$\text{Entry Rate} = V_S - 1.1V_S/\text{Time Difference}$$

(iii) The airplane lift coefficient, $C_L$, is then calculated for each test stall speed using the equation:

$$C_L = W/qS = 295.37(W)/(V_{s(e)}{}^2 S)$$

Where: $W$ = airplane test weight - lbs.
$q$ = dynamic pressure - lbs./ft.$^2$
$S$ = reference wing area - ft.$^2$
$V_{s(e)}$ = test stall speed corrected to knots equivalent airspeed.

(iv) The $C_L$ obtained for each stall is then corrected to the targeted c.g. position using the equation:

$$C_{LCG} = C_L(1+MAC/l_t)(CG_{std}-CG_{test})-\Delta C_{LT}$$

Where: MAC = Wing mean aerodynamic chord length - inches.

$l_t$ = Effective tail length, measured between the wing 25 percent MAC and the stabilizer 25 percent MAC - inches.

$CG_{std}$ = Forward c.g. limit at the pertinent weight - percent MAC/100

$CG_{test}$ = Actual test c.g. position - percent MAC/100

$\Delta C_{LT}$ = Change in $C_L$ due to engine thrust (if significant).

(v) For each targeted c.g. and external configuration, a plot of $C_{LCG}$ versus entry rate is constructed. The final stall $C_L$ is selected at an entry rate of 1.0 knot/second. (See Figure 29-2.)

(vi) For each final stall $C_L$, weight, wing flap, and external configuration, a plot of stall $C_L$ versus weight is constructed. (See Figure 29-3.) An initial negative slope of this plot may be caused by several factors:

(A) A decrease in $C_{LMAX}$ due to increasing Mach number (which increases as the stall speed goes up with weight);

(B) The fact that $C_{LMAX}$ is proportional to the rate of change of angle-of-attack, whereas the data are plotted at fixed airspeed bleed rate; and

(C) Minor adverse aeroelastic effects on the wings and high lift devices as weight (and therefore speed) increases. The inflection at the right end is caused typically by a less forward c.g. limit as weight increases.

(vii) For each approved configuration, a plot of stall speed versus weight is constructed. Stalling speeds are then calculated using the equation:

$$V_{S(e)} = \sqrt{295.37(W)/(C_L S)}$$

Where: W = a series of weights chosen as the independent variable - lbs.

$C_L$ = stall $C_L$ corresponding to the chosen weight. (See Figure 29-4.)

S = reference wing area - ft.$^2$

d. Stall Characteristics.

(1) Background. Since operational pilots may not be required, or trained, to fly to an angle-of-attack beyond that for stall warning, any exposure to the behavior of the airplane in an actual stall would be both unexpected and unfamiliar. Therefore, to assure a safe and expeditious recovery from an unintentional stall, it should not require any unusual piloting technique to successfully demonstrate compliance with § 25.203, nor should it require exceptional skill or repeated practice by the test pilot. The behavior of the airplane during the stall and recovery must be easily controllable using normally expected pilot reactions.

(2) Configuration.

(i) Stall characteristics should be investigated with wings level and in a 30-degree banked turn with both power on and power off in all configurations approved for normal operations.

(ii) Power-off stalls should be conducted at flight idle for the appropriate configuration. For propeller-driven airplanes, the propeller should be set in the normal low pitch (high r.p.m.) position.

(iii) For power-on stalls, thrust should be set to the value required to maintain level flight at a speed of $1.6V_S$ with flaps in the approach position, landing gear retracted, and at maximum landing weight. The approach flap position referred to is the maximum flap deflection used to show compliance with § 25.121(d), Approach Climb.

(iv) Stall characteristics testing is normally done at the aft c.g. limit, which is typically the most adverse; however, if the stall speed tests at forward c.g. indicate that marginal stall recovery characteristics may exist at forward c.g., compliance with § 25.203 should be shown for the most critical loading.

(v) Stalls must be demonstrated up to the maximum approved operating altitude to determine if there are any adverse compressibility effects on stall characteristics. These tests should be flown with gear and flaps up at the most adverse center of gravity. Thrust may be set, as required, to maintain approximately level flight and a 1 knot/second deceleration. A slight descent rate is permissible as long as the stall occurs at approximately the maximum approved altitude. Characteristics should be checked during a wings level stall and in a 30-degree banked turn.

(vi) For airplanes which are certificated for flight into known icing conditions, stall characteristics should be demonstrated with simulated ice shapes symmetrically attached to all surfaces which are not protected by anti-ice or de-icing systems.

(vii) For abnormal aerodynamic configurations covered by AFM procedures, high angle-of-attack characteristics should be evaluated down to either stall warning, or to an angle-of-attack equivalent to the AFM recommended landing approach speed divided by 1.3. If adequate controllability is present at either of these conditions, it is not necessary to stall the airplane. "Adequate controllability" means that it is possible to produce and to correct pitch, roll, and yaw by unreversed use of the flight controls, and that there are no uncommanded airplane motions due to aerodynamic flow breakdown. If stall warning is used as the end point, then it should be demonstrated that the airplane is safely controllable and maneuverable when flown at the recommended operating speed.

(viii) Stall characteristics should also be demonstrated with the maximum allowable asymmetric fuel loading. Requirements are as specified in §§ 25.203(a) and (c).

(3) Procedures.

(i) The airplane should be trimmed for hands-off flight at a speed 20 percent to 40 percent above stall speed, with the appropriate power setting and configuration. Then, using only the primary longitudinal control, a deceleration (entry rate) of up to 1 knot/second is maintained until the stall is reached. Both power and pilot selectable trim should remain constant throughout the stall and recovery (angle-of-attack has decreased to the point of no stall warning.).

(ii) The same trim reference (for example, $1.3V_S$) should be used for both the stall speeds and characteristics testing. For all stall testing, the trim speed is based on the performance stall speeds which are (or will be) shown in the AFM.

(iii) If the airplane has a stall prevention system, stall characteristics should be evaluated at entry rates up to 3 knots/second, to evaluate any adverse effects of entry rate on the trip point of the device.

(iv) For those airplanes where stall is defined by full nose-up longitudinal control for both forward and aft c.g., the time at full aft stick should be the same during characteristics testing as was used for stall speed definition.

(v) Normal use of lateral/directional control must produce a roll in the applied direction up to the point where the airplane is considered stalled.

e. Stalls: Critical Engine Inoperative.

(1) Explanation. The purpose of this testing is to ensure that in an uncontrollable maneuver.

(2) Procedures.

(i) The configuration should be as follows:

(A) Heavy weight (in order to separate the stall speed and the air minimum control speed as much as possible).

(B) Aft c.g. position.

(C) Wing flaps and high lift devices retracted.

(D) Landing gear retracted.

(E) Trim speed from $1.2V_S$ to $1.4V_S$.

(F) Engine power at 75 percent of maximum continuous thrust (MCT) on all operating engines and, for turbine engines, the critical engine at flight idle or, for propeller driven airplanes, the critical engine feathered or at approximately zero thrust.

(ii) The test procedure is the same as for a symmetrical power stall (see § 25.201(c)) and can be flown at any altitude where 75 percent MCT can be maintained. There is some contradiction, however, between the requirements of § 25.201, which specify that the stall be done in "straight flight" and the requirements of § 25.205, which imply that it should be done with wings level. With asymmetric thrust, it is not possible to achieve both of these conditions simultaneously. If the maneuver is flown wings level, the airplane will be sideslipping into the inoperative engine, which is obviously not "straight flight." If a constant track equal to the airplane heading is desired, the airplane must be flown at zero sideslip.

(iii) The original CAR 4b requirements were written for propeller driven airplanes, which normally have a significant rolling moment due to asymmetric lift induced by propwash. These requirements specified that the asymmetric power to be used was 75 percent MCT, or any lesser value necessary to insure that lateral control was maintained at the stall. The statement that ". . .the wings be held laterally level. . ." meant that sufficient lateral control should be available to prevent a roll rate from developing. It was never intended to force the airplane into a sideslip just to maintain wings exactly level. As with all other stalls required by the regulations, every effort should be made to maintain zero sideslip. In most cases, this will require a slight bank (2 - 3 degrees) into the operating engine(s). The method used to fly at zero sideslip should be repeatable in service and should be described in the recommended engine-out procedures.

(iv) When doing an engine-out stall, airspeed should be reduced by use of the pitch control, while maintaining lateral control until one of the following occurs:

(A) The airplane stalls,

(B) A rudder pedal force of 150 lbs. is achieved, or

(C) Full rudder deflection is reached.

(v) If full rudder deflection (or 150 lbs. pedal force) is required to maintain straight flight prior to the stall, the maneuver should be terminated at this point. For those airplanes that run out of lateral control, it is permissible to reduce the power on the operating engines until adequate roll control is available to complete the stall. After stall recovery is initiated, it is permissible to throttle back the operating engine(s).

f. Stall Warning.

(1) Explanation. The purpose of these stall warning requirements is to provide an adequate spread between warning and stall to allow the pilot time to recover without inadvertently stalling the airplane.

(2) Background. To be acceptable, a stall warning must have the following features:

(i) Distinctiveness. The stall warning indication must be clear and distinct to a degree which will ensure positive pilot recognition of an impending stall.

(ii) Timeliness. The stall warning should normally begin at a speed not less than 7 percent above stall speed. A lesser margin may be acceptable depending on the probability of an inadvertent stall following stall warning recognition, and how much difference there is between the speed at which the airplane stalls (stall identification), and the minimum speed allowed under § 25.103(a).

(iii) Consistency. The stall warning must be reliable and repeatable. The warning must occur with flaps and gear in all normally used positions in both straight and turning flight. The warning may be furnished naturally through the inherent aerodynamic characteristics of the airplane, or artificially by a system designed for this purpose. If artificial stall warning is provided for any airplane configuration, it must be provided for all configurations.

(iv) An artificial stall warning indication that is a solely visual device which requires attention in the cockpit, inhibits cockpit conversation, or in the event of malfunction, causes distraction which would interfere with safe operation of the airplane, is not acceptable.

(3) Procedures. Stall warning tests are normally conducted in conjunction with the stall testing required by §§ 25.103 (speeds) and 25.203 (characteristics).

(4) Data Acquisition and Reduction. The stall warning speed and type and quality of warning should be noted. The speed at which acceptable stall warning begins should then be compared to the stall speed as defined in paragraph (3) above to determine if the required margin exists.

g. Accelerated Stall Warning. Determine that adequate stall warning occurs in turning flight under expected conditions of flight for takeoff, enroute, and approach/landing configurations at aft c.g. and heavy weight.

h. Maneuver Margins. Determine that adequate maneuvering capability exists prior to stall warning at $V_2$, all-engines takeoff speed, final takeoff speed (§ 25.121(c)), and $V_{REF}$ at forward c.g. and heavy weight for each appropriate flap setting.

FIGURE 29-1. STALL TEST TIME HISTORY

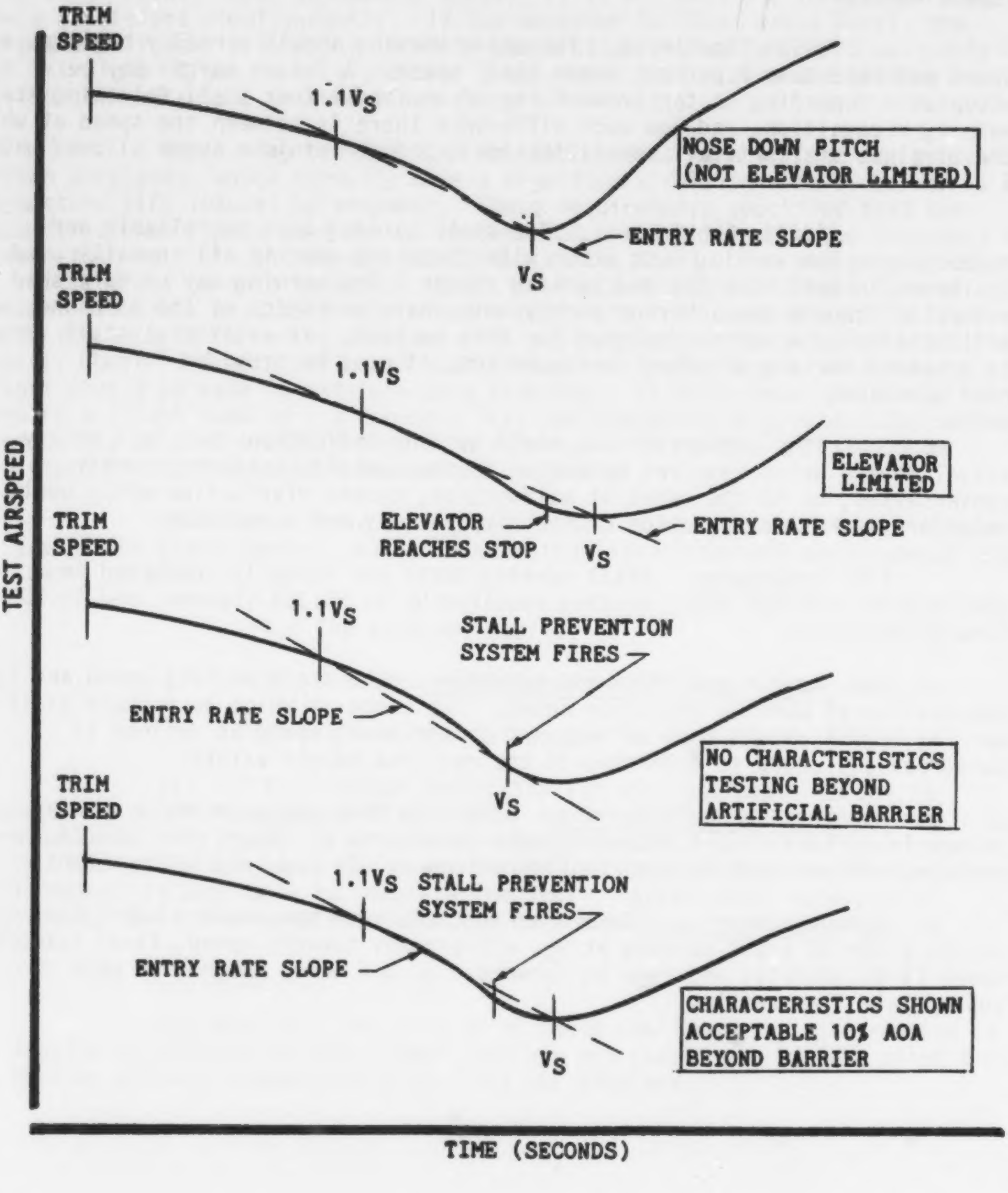


FIGURE 29-2. STALL $C_{LCG}$ VS ENTRY RATE

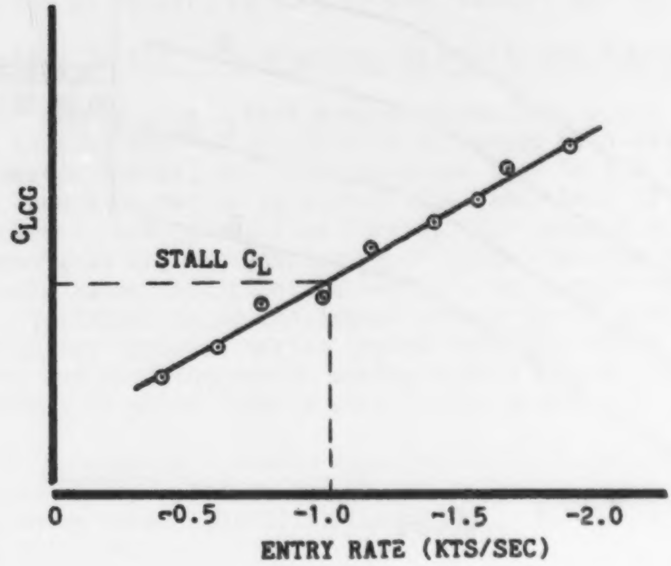


FIGURE 29-3. STALL $C_L$ VS WEIGHT AND FLAP SETTING

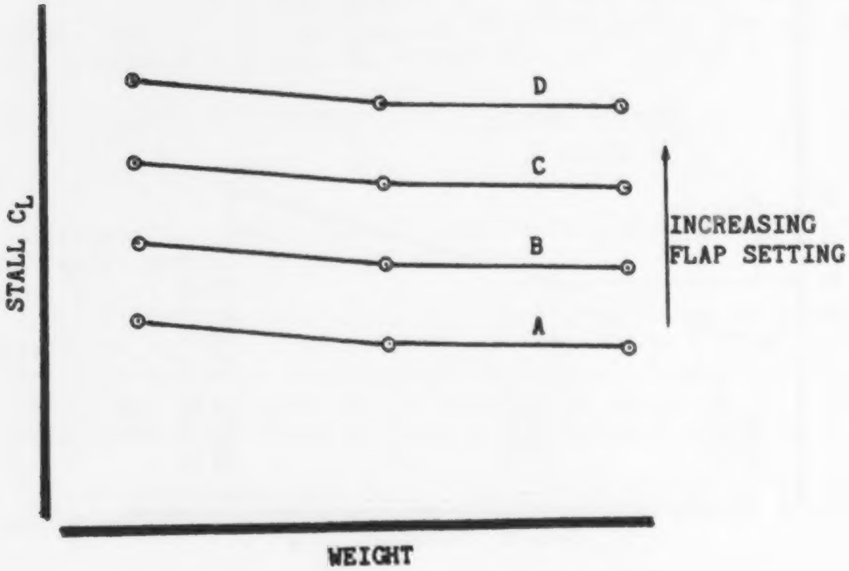


FIGURE 29-4. STALL SPEEDS VS WEIGHT AND FLAP SETTING

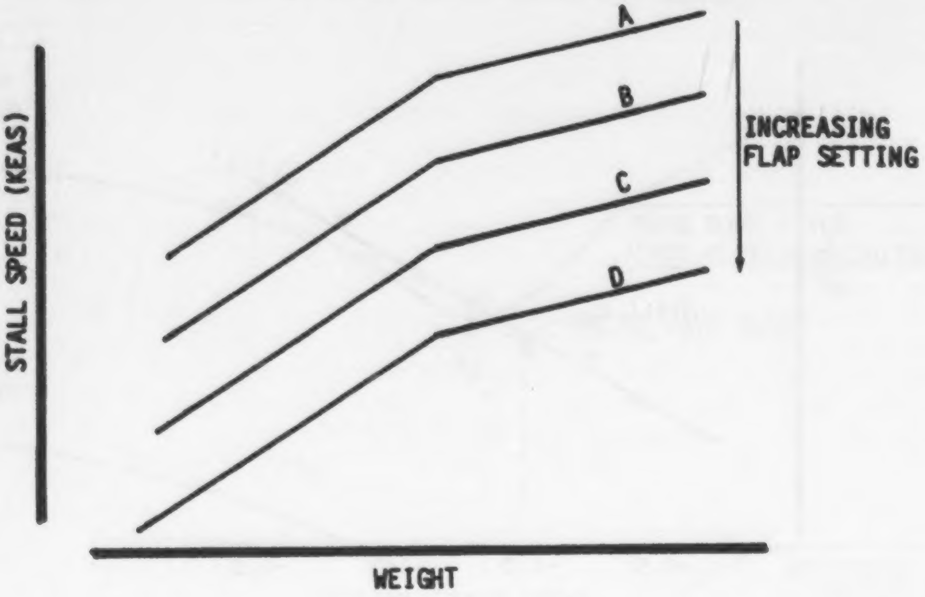
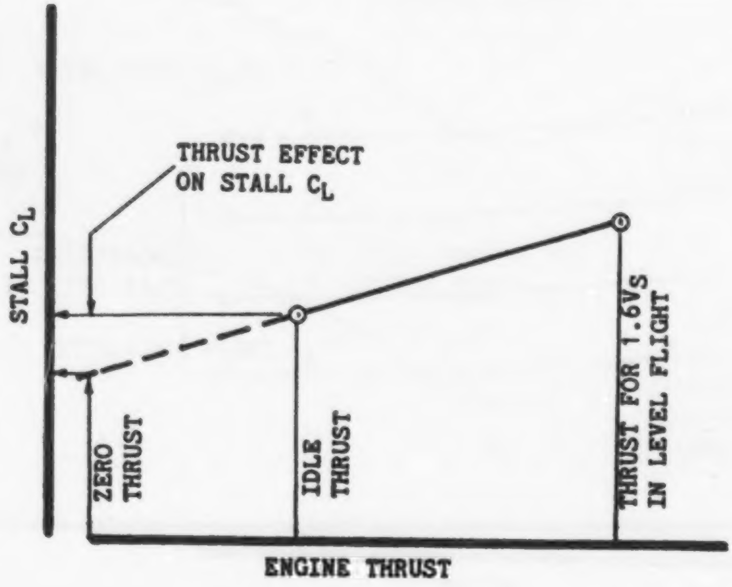


FIGURE 29-5. THRUST EFFECT ON STALL $C_L$



## Section 7. GROUND AND WATER HANDLING CHARACTERISTICS

### 30. GENERAL.

a. Applicable Federal Aviation Regulations (FAR). The applicable regulations are §§ 25.231, 25.233, 25.235, 25.237, and 25.239 of the FAR.

b. Section 25.231 - Longitudinal Stability and Control.

(1) Explanation. Test program objectives would not be expected to demonstrate taxiing over rough surfaces at speeds high enough to approach structural design limits, nor is it expected that in the test program the airplane be landed harder or at higher sink rates than it will ever encounter in service. However, new or modified landing gear systems would be evaluated on rough surfaces that are representative of normal service and landings conducted at various sink rates sufficient to identify any dangerous characteristics or tendencies. Variables to be considered are center of gravity and taxi speed. The cockpit motion dynamics during ground handling should not impede control of the airplane, and pitching motion during bounce should not create static pitch control problems or pilot induced oscillation tendencies.

(2) Procedures. Ground handling tests at speeds normally expected in service should be conducted on smooth and rough surfaces which are likely to be encountered under normal operating conditions. Particular attention should be paid to the following:

(i) Brakes. The adequacy of the brakes when maneuvering on the ground and the tendency of the brakes to cause nosing-over should be investigated. Any bad tendency will normally be exaggerated when taxiing in a strong cross or tail wind.

(ii) Seaplanes and Amphibians. The most adverse water conditions safe for taxiing, takeoff, and landing must be established. The use and limitations of reverse thrust must be determined.

c. Section 25.233 - Directional Stability and Control.

(1) Explanation. None.

(2) Procedures. Taxi, takeoff, and landing should be conducted in all configurations under normal operating conditions.

(i) There may be no uncontrollable ground-looping tendency in 90-degree crosswinds, up to a wind velocity of 20 knots or $0.2V_{SO}$, whichever is greater (except that the wind velocity need not exceed 25 knots) at any speed at which the airplane may be expected to be operated on the ground. This may be shown while establishing the 90-degree crosswind component required by § 25.237.

(ii) Landplanes must be satisfactorily controllable, without exceptional piloting skill or alertness in power-off landings at normal landing speed, without using brakes or engine power to maintain a straight path. This may be shown during power-off landings made in conjunction with other tests.

(iii) The airplane must have adequate directional control during taxiing. This may be shown during taxiing prior to takeoffs made in conjunction with other tests.

d. Section 25.235 - Taxiing Condition. [RESERVED]

e. Section 25.237 - Wind Velocities.

(1) Explanation.

(i) Landplanes.

(A) There must be a 90-degree crosswind component established that is shown to be safe for takeoff and landing on dry runways.

(B) The airplane must exhibit satisfactory controllability and handling characteristics in 90-degree crosswinds at any ground speed at which the airplane is expected to operate.

(ii) Seaplanes and Amphibians.

(A) There must be a 90-degree crosswind component established that is shown to be safe for takeoff and landing in all water conditions that may reasonably be expected in normal operation.

(B) There must be a wind velocity established for which taxiing is safe in any direction under all water conditions that may reasonably be expected in normal operation.

(iii) Crosswind Demonstration. A 90-degree crosswind component at 10 meters (as required by § 25.21(f)) of at least 20 knots or $0.2V_{SO}$, whichever is greater, except that it need not exceed 25 knots, must be demonstrated during type certification tests. There are two results possible:

(A) A crosswind component value may be established which meets the minimum requirements but is not considered to be a limiting value for airplane handling characteristics. This "demonstrated" value should be included as information in the AFM.

(B) A crosswind component value may be established which is considered to be a maximum limiting value up to which it is safe to operate for takeoff and landing. This "limiting" value should be shown in the Operating Limitations section of the AFM.

(2) Procedures.

(i) Configuration. These tests should be conducted in the following configurations:

(A) At light weight and aft c.g. (this is desirable; however, flexibility should be permitted).

(B) Normal takeoff and landing flap configurations using the recommended procedures.

(C) Normal usage of thrust reversers. Particular attention should be paid to any degradation of rudder effectiveness due to thrust reverser airflow effects.

(D) Yaw dampers/turn coordinator On, or Off, whichever is applicable.

(ii) Test Procedure and Required Data. Three takeoffs and 3 landings, with at least one landing to a full stop, should be conducted in a 90-degree crosswind component of at least 20 knots or $0.2V_{SO}$, whichever is greater, except that for Amendment 25-42 only it need not exceed 25 knots. For each test condition, a qualitative evaluation by the pilot of airplane control capability, forces, airplane dynamic reaction in gusty crosswinds (if available), and general handling characteristics should be conducted. The airplane must be satisfactorily controllable without requiring exceptional piloting skill or strength. Wind data from the INS systems, tower, or portable ground recording stations should be corrected to a 90-degree crosswind component and to a height of 10 meters.

f. Section 25.239 - Spray Characteristics, Control, and Stability on Water.

(1) Explanation. These characteristics should be investigated at the most adverse weight/c.g. combinations.

(2) Procedures.

(i) The spray characteristics and, in particular, the pilot view during the initial takeoff run, should allow sufficient view in order to maintain a reasonable track over the water. Since not all seaplane operations are on open lakes or bays but can be on rivers or channels, the directional control and view should be sufficient enough to stay within the channel confines.

(ii) The tendency of the wing floats or sponsons to submerge and/or cause waterloops should be evaluated during the crosswind testing. During the step taxiing evaluations, the floats should also be evaluated for any tendency to bury and either cause waterlooping or damage. The procedures used to avoid undesirable characteristics should be included in the AFM.

(iii) During low speed taxi, the effectiveness of the water rudders and/or asymmetric thrust should be evaluated in view of the types of maneuvering to be expected in service. If reverse thrust is to be used, it too should be evaluated in terms of ease of accomplishment and crew coordination.

(iv) If an amphibian is intended to be "beached" or run up a ramp, the handling characteristics and ability to maneuver onto the ramp should be evaluated. Forward c.g. is generally more critical. The procedures should be included in the AFM. There should be no undue tendency to damage the bow or other structure.

(v) Engine failure of the critical engine at any time during the takeoff run should be evaluated. No dangerous porpoising, swerving, or waterlooping should result.

(vi) There should be no undue tendency to porpoise and no extraordinary skill or alertness should be required to control porpoising.

(vii) Spray impingement on the airframe (control surfaces, etc.) should be evaluated to assure the resulting loads are within acceptable limits.

(viii) The above evaluations should be performed in the airplane on the water rather than by analysis or model testing. Analysis and/or model testing may be used to point out the problem areas but should not be substituted for actual testing.

## Section 8. MISCELLANEOUS FLIGHT REQUIREMENTS

### 31. VIBRATION AND BUFFETING - § 25.251.

a. Explanation.

(1) The testing required by Subpart C of Part 25 covers the vibration extremes expected in service. The Federal Aviation Administration and the applicant's flight tests should assure that the regulatory limits are not exceeded. Flight testing should not be conducted beyond where structural (Subpart C) tests and calculations have been completed.

(2) For §§ 25.251(b) and (c), vibration and buffeting is considered excessive when it is determined that it:

(i) May cause structural damage or, if sustained over an extended period of time, could lead to structural fatigue;

(ii) May cause pilot fatigue or annoyance which interferes with operation of the airplane or management of the airplane systems; or,

(iii) Interferes with flight instrument readability.

(3) No perceptible buffeting is permitted in the cruise configuration as required by § 25.251(d). Weight and/or altitude Airplane Flight Manual (AFM) limitations may need to be imposed to comply with this criterion. Reasonable buffet during the deployment of spoilers and other high drag devices is permitted to the extent allowed under §§ 25.251(b) and (c) as described above.

(4) A determination of a buffet onset envelope is to be established for the ranges of airspeed and/or Mach number, weight, altitude, and load factor for which the airplane is to be certificated. This envelope should be made a part of the AFM in accordance with § 25.1585(c). This AFM data should be valid criterion for forward c.g. conditions or correctable to forward c.g. by the use of AFM procedures. This boundary should be established by pilot event as there is no established criterion for buffet level at the pilot station. A normal acceleration of ±.05g has been proposed; however, that will vary from airplane to airplane and may also be affected by the dynamic response of the accelerometer.

(5) Modifications to airplanes, particularly modifications which may affect airflow about the wing, should be evaluated for affect on vibration and buffeting characteristics, changes in the speeds for onset of buffet, and maneuvering characteristics beyond buffet onset. This change may not only impact the buffet boundary envelope but may change the acceptability of the $V_{MO}/M_{MO}$ or $V_{DF}/M_{DF}$ derived from the unmodified airplane. If this occurs, the maximum operating speed and dive speed may be reduced. However, the applicable speed spread margin regulations remain in effect. Systems and flight characteristics affected by the reduced maximum speeds should also be reevaluated. Indicator markings, overspeed horns, etc. should be reset as necessary if the airplane is to remain in the transport category.

(6) Section 25.571 specifies design criteria for fatigue tolerance of airplane structure. During the flight test program, including function and reliability (F&R), evidence of vibration of a magnitude below that leading to control problems, etc., as described in §§ 25.251(b) and (c), should be analyzed for fatigue implications.

(7) On swept-wing airplanes, undesirable pitch-up maneuvering characteristics can occur as the center of lift moves inboard and forward with increasing g, due to shock-wave induced separation and/or as wing load alleviation systems unload the wingtips. Straight-wing airplanes can also exhibit similar characteristics; therefore, new airplanes and those modified in a manner that may affect the spanwise lift distribution or produce undesirable pitching moment as a function of g, or increase the exposure to high altitude buffet encounters, should be evaluated as described herein.

(8) It has been determined that a positive slope of the stick force versus g ($F_s/g$) relationship is not necessarily required at speeds and g combinations beyond $V_{FC}/M_{FC}$ and/or buffet onset. However, § 25.251(e) requires that "probable inadvertent excursions beyond the boundaries of buffet" may not result in "unsafe conditions." Section 25.251(e) does not adequately describe the required maneuvering stability characteristics intended in demonstrating compliance. In order to assure that no "unsafe conditions" are encountered in maneuvering flight, maneuvering flight evaluations to demonstrate satisfactory maneuvering stability are described herein. A determination of the longitudinal maneuvering characteristics should be made to assure the airplane is safely controllable and maneuverable in the cruise configuration to assure there is no danger of exceeding the airplane limit load factor and that the airplane's pitch response to primary longitudinal control is predictable to the pilot.

b. Procedures.

(1) Section 25.251(a). The test procedures outlined below will provide the necessary flight demonstrations for compliance with § 25.251(a).

(2) Section 25.251(b). The airplane should be flown at $V_{DF}/M_{DF}$ at several altitudes from the highest practicable cruise altitude to the lowest practicable altitude. The test should be flown starting from trimmed flight at $V_{MO}/M_{MO}$ at a thrust setting not exceeding maximum continuous power. The airplane gross weight should be as high as practicable for the cruise condition with the c.g. at or near the aft limit.

(i) High drag devices should also be deployed at $V_{DF}/M_{DF}$ (spoilers and speed brakes); thrust reversers, if designed for inflight deployment, should be deployed at their limit speed conditions.

(ii) Airplanes equipped with pneumatic de-icer boots should be evaluated to $V_{DF}/M_{DF}$ with de-icing on and off (if automatic) and not operating. If the applicant desires to restrict the maximum operating speed ($V_{NE}$ or $V_{MO}/M_{MO}$) to a lower value with de-icing on, it should be shown that excessive vibration or buffeting does not occur at speeds of the new $V_{NE}$+10 percent of $V_{DF}$ or the new $V_{MO}/M_{MO}$+20 percent of $V_{DF}$.

(3) Section 25.251(c). The weight of the airplane should be as heavy as practical commensurate with achieving the maximum certificated altitude.

(4) Section 25.251(d). It should be shown by flight tests that perceptible buffeting does not occur in straight flight in the cruise configuration at any speed up to $V_{MO}/M_{MO}$. This test should be conducted at the highest cruise weight and altitude expected in service.

(5) Section 25.251(e). This requirement provides criteria for evaluation of maneuvering stability in cruise flight under load factor conditions up to and beyond the onset of buffet. The determination of compliance with § 25.251(e) using flight test data from maneuvers conducted well into buffet is extremely difficult due to the dynamics of this type of maneuver and the establishment of the $F_s/g$ relationship from such data. The pilot flying the airplane needs to evaluate the airplane characteristics under such conditions. In this regard, Figures 31-1 and 31-2 illustrate general airplane responses and do not necessarily indicate required quantitative flight test results.

(i) Airplanes should be evaluated at the most aft c.g. in accordance with the following criteria:

(A) For all weight/altitude combinations where buffet onset occurs at various load factors between approximately +1g and +2g, the longitudinal control force ($F_s$) characteristics of §§ 25.255(b)(1) and (2) apply prior to encountering that buffet onset (see buffet free regions of Figures 31-1 and 31-2).

(B) Under the airplane weight/altitude/speed combinations of (A) above, but at load factors beyond buffet onset, the following $F_s$ characteristics apply (see buffet regions of Figures 31-1 and 31-2):

(1) The evaluation should proceed to a g level that will allow recovery to be accomplished near +2.5g, unless sufficient buffet or other phenomena (natural, artificial, or a combination) of such intensity exists that is a strong and effective deterrent to further pilot application of nose-up longitudinal control force (as in § 25.201(d)(2)) so that there is no danger of exceeding the airplane limit load factor (Ref. § 25.143(b)).

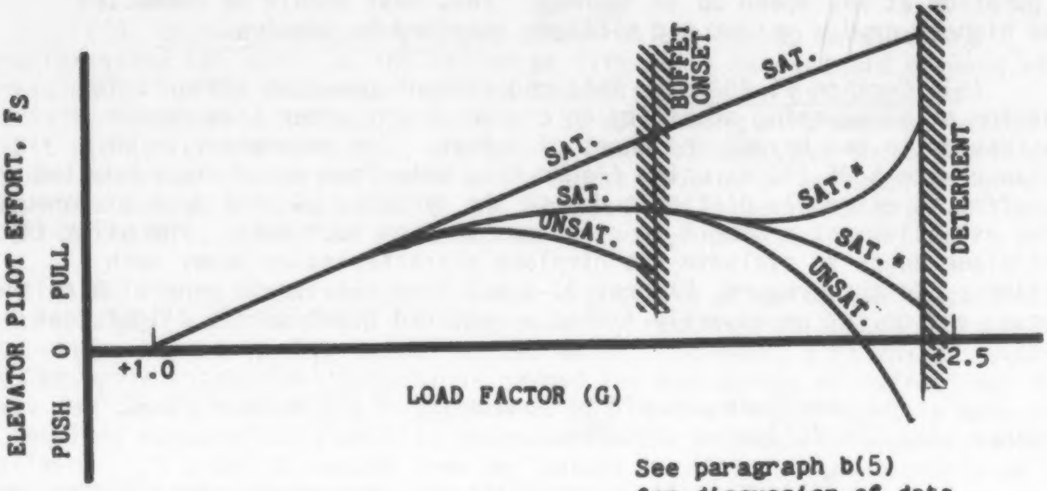
(2) Any pitching tendency (uncommanded changes in load factor) shall be mild and readily controllable.

(3) Sufficient control shall be available to the pilot, through unreversed use of only the primary longitudinal control, to effect a prompt recovery to +1g flight from the load factors described herein.

(4) The airplane's pitch response to primary longitudinal control shall be predictable to the pilot.

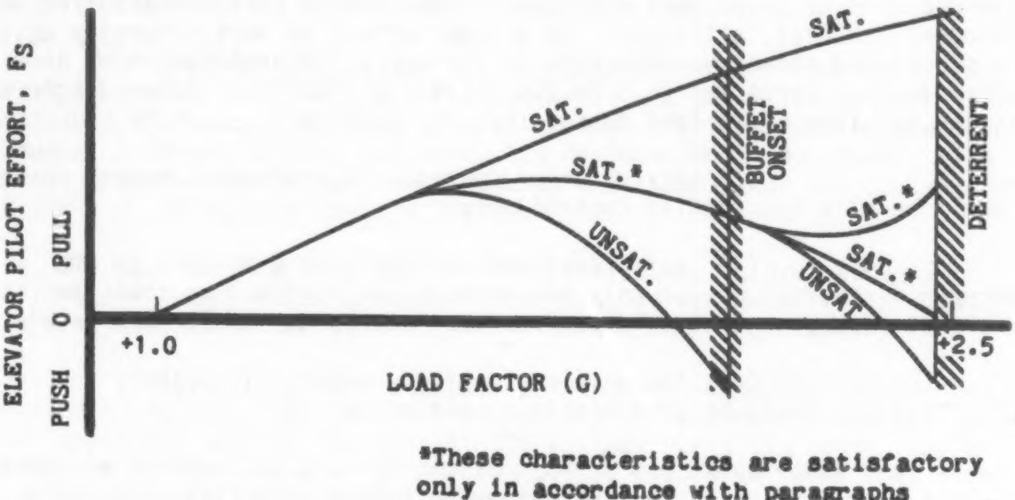
(ii) Experience has shown that maneuvering evaluations conducted at the highest Mach and the highest weight and altitude (W/delta) combination may not necessarily produce the most critical results. Equally important is the

FIGURE 31-1. MANEUVERING CHARACTERISTICS
Speeds Up to the Lesser of $V_{FC}$ or $M_{FC}$ or
Buffet Onset at 1G



**See paragraph b(5) for discussion of data beyond buffet onset.**

FIGURE 31-2. MANEUVERING CHARACTERISTICS
Speeds Between Figure 31-1 and $V_{DF}$ or $M_{DF}$



***These characteristics are satisfactory only in accordance with paragraphs b(5)(i)(A) and(B).**

character of the buffet buildup, e.g., slowly increasing or rapid rise, and the g at which it starts. Conditions associated with buffet onset near 2g at Mach numbers below $M_{MO}$ have sometimes yielded the most critical characteristics. Therefore, a sufficient spread of conditions should be evaluated.

## 32. HIGH SPEED CHARACTERISTICS - § 25.253.

### a. Explanation.

(1) The maximum flight demonstrated speed, $V_{DF}/M_{DF}$, is used when establishing $V_{MO}/M_{MO}$ and the associated speed margins under the provisions of § 25.1505. Both $V_{MO}$ and $M_{MO}$ are then evaluated during flight tests for showing compliance with § 25.253.

(2) The pitch upset described in § 25.335(b), Amendment 25-23, or § 25.1505, pre-Amendment 25-33, is for a design criteria only. The operational upsets expected to occur in service for pitch, roll, yaw, and combined axis upsets are covered under § 25.253.

(3) In general, the same maneuvers should be accomplished in both the dynamic pressure and Mach critical ranges. All maneuvers in either range should be accomplished at thrust and trim points appropriate for the specific range. It must be realized that some maneuvers in the Mach range may be more critical for some airplanes due to drag rise characteristics, and that at high altitudes a lower gross weight may be required to achieve the maximum approved operating altitude and Mach/airspeed conditions.

(4) The airplane's handling characteristics in the high speed range should be investigated in terms of anticipated action on the part of the flightcrew during normal and emergency conditions.

(5) At least the following factors should be considered in determining the necessary flight tests.

(i) Effectiveness of longitudinal control at $V_{MO}/M_{MO}$ and up to $V_{DF}/M_{DF}$.

(ii) Effect of any reasonably probable mistrim on upset and recovery.

(iii) Dynamic and static stability.

(iv) The speed increase that results from likely passenger movement when trimmed at any cruise speed to $V_{MO}/M_{MO}$.

(v) Trim changes resulting from compressibility effects.

(vi) Characteristics exhibited during recovery from inadvertent speed increase.

(vii) Upsets due to vertical and horizontal gusts (turbulence).

(viii) Speed increases due to horizontal gusts and temperature inversions.

(ix) Effective and unmistakable aural speed warning at $V_{MO}$ plus 6 knots, or $M_{MO}$ plus 0.01M.

(x) Speed and flightpath control during application of deceleration devices.

(xi) The manageability of control forces resulting from the application of deceleration devices.

(6) The factors outlined in § 25.335(b)(2) and in paragraph (5) above, should be considered in establishing minimum speed margins during type certification programs for the Mach and airspeed ranges as follows:

(i) Increment allowance for horizontal gusts (0.02M).

(ii) Increment allowance for penetration of jet stream or cold front (0.015M).

(iii) Increment allowance for production tolerances in airspeed systems (0.005M), unless larger differences are found to exist.

(iv) Increment allowance for production tolerances of overspeed warning error (0.01M), unless larger tolerances or errors are found to exist.

(v) Increment allowance $\Delta M$ due to speed overshoot from $M_{MO}$ established by upset during flight tests in accordance with § 25.253 should be added to the values for production differences and equipment tolerances, and the minimum acceptable combined value should not be less than .05M between $M_{MO}$ and $M_D/M_{DF}$. The value of $M_{MO}$ then should not be greater than the lowest value obtained from each of the following equations and from § 25.1505:

$$M_{MO} \leq M_D/M_{DF} - \Delta M - .005M - .01M$$

or

$$M_{MO} \leqq M_D/M_{DF} - .05M$$

(vi) At altitudes where $V_{MO}$ is limiting, the allowances of paragraphs (6)(i) and (ii) are applicable when the Mach number increment is converted to the units used in the presentation of $V_{MO}$.

(vii) At altitudes where $V_{MO}$ is limiting, the increment allowance for production differences of airspeed systems and production tolerances of overspeed warning errors are 3 and 6 knots, respectively, unless larger differences or errors are found to exist.

(viii) Increment allowance $\Delta V$ due to speed overshoot from $V_{MO}$, established by upset during flight tests in accordance with § 25.253, should be

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added to the values for production differences and equipment tolerances. The value of $V_{MO}$ should not be greater than the lowest obtained from the following equation and from § 25.1505:

$V_{MO} \leq V_D/V_{DF} - \Delta V$-3 knots (production differences)-6 knots (equipment tolerances).

b. Regulations Affected. These criteria refer to certain provisions of Part 25 of the Federal Aviation Regulations (FAR). They may also be used in showing compliance with the corresponding provisions of the former Civil Air Regulations (CAR) in the case of airplanes to which those regulations are applicable. Other affected FAR are as follows:

| | |
|---|---|
| Section 25.175(b) | Demonstration of static longitudinal stability. |
| Section 25.251 | Vibration and buffeting. |
| Section 25.253 | High-speed characteristics. |
| Section 25.335(b) | Design dive speed, $V_D$. |
| Sections 25.1303(b)(1) and (c) | Flight and navigation instruments. |
| Section 25.1505 | Maximum operating limit speed. |

c. Procedures. Using the speeds $V_{MO}/M_{MO}$ and $V_{DF}/M_{DF}$ determined in accordance with §§ 25.1505 and 25.251, respectively, and the associated speed margins, the airplane should be shown to comply with the high-speed characteristics of § 25.253. Unless otherwise stated, the airplane characteristics should be investigated at the most critical speed up to and including $V_{MO}/M_{MO}$, and the recovery procedures used should be those selected by the applicant, except that the normal acceleration during recovery should be no more than 1.5g (total). Testing should be conducted at the critical c.g.

(1) Center of Gravity Shift. The airplane should be upset by the center of gravity shift corresponding to the forward movement of a representative number of passengers (and/or serving carts) depending upon the airplane interior configuration. The airplane should be permitted to accelerate until 3 seconds after effective overspeed warning.

(2) Inadvertent Speed Increase. Simulate an evasive control application when trimmed at $V_{MO}/M_{MO}$, by applying sufficient forward force to the pitch control to produce 0.5g (total) for a period of 5 seconds, after which recovery should be effected at not more than 1.5g (total).

(3) Gust Upset. In the following three upset tests, the values of displacement should be appropriate to the airplane type and should depend upon airplane stability and inertia characteristics. The lower and upper limits should be used for airplanes with low and high maneuverability, respectively.

(i) With the airplane trimmed in wings-level flight, simulate a transient gust by rapidly rolling to the maximum bank angle appropriate for the airplane, but not less than 45 degrees nor more than 60 degrees. The rudder and longitudinal control should be held fixed during the time that the required bank is being attained. The rolling velocity should be arrested at this bank angle. Following this, the controls should be abandoned for a minimum of 3 seconds after $V_{MO}/M_{MO}$ or 10 seconds, whichever occurs first.

(ii) Perform a longitudinal upset from normal cruise. Airplane trim is determined at $V_{MO}/M_{MO}$ using power/thrust required for level flight but with not more than maximum continuous power/thrust. This is followed by a decrease in speed after which an attitude of 6-12 degrees nose down as appropriate for the airplane type is attained with the power/thrust and trim initially required for $V_{MO}/M_{MO}$ in level flight. The airplane is permitted to accelerate until 3 seconds after $V_{MO}/M_{MO}$. Force limits of § 25.143 for temporary application apply.

(iii) Perform a two-axis upset, consisting of combined longitudinal and lateral upsets. Perform the longitudinal upset, as in paragraph (ii) above, and when the pitch attitude is set, but before reaching $V_{MO}/M_{MO}$, roll the airplane 15-25 degrees. The established attitude should be maintained until 3 seconds after overspeed warning.

(4) Leveling Off from Climb. Perform transition from climb to level flight without reducing power below the maximum value permitted for climb until overspeed warning. Recovery should be accomplished by applying not more than 1.5g (total).

(5) Descent from Mach Airspeed Limit Altitude. A descent should be performed at the airspeed schedule defined by $M_{MO}$ and continued until an overspeed warning occurs, at which time recovery should be accomplished without exceeding 1.5g (total).

## 33. OUT-OF-TRIM CHARACTERISTICS - § 25.255.

a. Explanation. Certain early, trimmable stabilizer equipped jet transports experienced "jet upsets" which resulted in high speed dives. When the airplane was mistrimmed in the nose-down direction and allowed to accelerate to a high airspeed, it was found that there was insufficient elevator power to recover. Also, the stabilizer could not be trimmed in the nose-up direction because the stabilizer motor stalled due to excessive airloads imposed on the horizontal stabilizer. As a result, a special condition was developed and applied to most Part 25 airplanes with trimmable stabilizers. With certain substantive changes, it was adopted as § 25.255, effective with Amendment 25-42. While these background problems seem to be generally associated with airplanes having trimmable stabilizers, it is clear from preamble discussions (Part 25, Change 7, dated March 1, 1978) that § 25.255 applies "regardless of the type of trim system used in the airplane." Section 25.255 is structured to give protection against the following unsatisfactory characteristics during mistrimmed flight in the higher speed regimes.

(1) Changes in maneuvering stability leading to overcontrolling in pitch.

(2) Inability to achieve at least 1.5g for recovery from upset due to excessive control forces.

(3) Inability of the flightcrew to apply the control forces necessary to achieve recovery.

(4) Inability of the pitch trim system to provide necessary control force relief when high control force inputs are present.

b. Reference Regulation. Section 25.255, as amended through Amendment 25-42.

c. Discussion of The Regulation.

(1) Section 25.255(a) is the general statement of purpose. Maneuvering stability may be shown by a plot of applied control force versus normal acceleration at the airplane center of gravity. Mistrim must be set to the greater of the following:

(i) Section 25.255(a)(1). A 3-second movement of the longitudinal trim system at its normal rate for the particular flight condition with no aerodynamic load. Since many modern trim systems are variable rate systems, this subsection requires that the maneuver condition be defined and that the no-load trim rate for that condition be used to set the degree of mistrim required.

(ii) Section 25.255(a)(2). The maximum mistrim that can be sustained by the autopilot while maintaining level flight in the high speed cruising condition. The high speed cruising condition corresponds to the speed resulting from maximum continuous power or thrust, or $V_{MO}/M_{MO}$, whichever occurs first. Maximum autopilot mistrim may be a function of several variables, and the degree of mistrim should therefore correspond to the conditions of test.

(2) Section 25.255(b) establishes the basic requirement to show positive maneuvering stability throughout a specified acceleration envelope at all speeds to $V_{FC}/M_{FC}$, and the absence of longitudinal control force reversals throughout that acceleration envelope at speeds between $V_{FC}/M_{FC}$ and $V_{DF}/M_{DF}$. (Later subsections (d) and (e) recognize that buffet boundary and control force limits will limit the acceleration actually reached; this does not account for Mach trim gain, etc.).

(3) Section 25.255(c) requires that the investigation of maneuvering stability (§ 25.255(b)) include all attainable acceleration values between -1g and +2.5g. Sections 25.333(b) and 25.337, to which it refers, limit the negative g maximum to 0g at $V_D$. Section 25.251 further limits the g to that occurring in probable inadvertent excursions beyond the buffet onset boundary at those altitudes where the buffet is a factor.

(4) Section 25.255(c)(2) would allow extrapolations to be used. For example, if the stick force gradient between 0 and +2g agrees with predicted data, extrapolation to -1g and 2.5g should be allowed.

(5) Section 25.255(d) requires that flight test at the marginal condition to the applicable limits of paragraph (b)(1) be accomplished if marginal conditions exist during flight test.

(6) Section 25.255(e), limits the investigation to the required structural strength limits of the airplane and maneuvering load factors associated with probable inadvertent excursions beyond the boundary of the buffet onset envelope. It also accounts for the fact that speed may increase substantially during test conditions in the -1 to +1 range. It limits the entry speed to avoid exceeding $V_{DF}/M_{DF}$.

(7) Section 25.255(f) requires that in the out-of-trim condition of paragraph (a) it must be possible to produce at least 1.5g during recovery from the overspeed condition of $V_{DF}/M_{DF}$. If adverse flight characteristics preclude the attainment of this load factor at the highest altitude reasonably expected for recovery to be initiated at $V_{DF}/M_{DF}$ following an upset at high altitude, the flight envelope (c.g., $V_{DF}/M_{DF}$, altitude, etc.) of the airplane should be restricted to a value where 1.5g is attainable. If trim must be used for the purpose of obtaining 1.5g, it must be shown to operate with the primary control surface loaded to the least of three specified values.

(i) The force resulting from application of the pilot limit loads of § 25.397 (300 lbs.).

(ii) The control force required to produce 1.5g (between 125 and 300 lbs.).

(iii) The control force corresponding to buffeting or other phenomena of such intensity that it is a strong deterrent to further application of primary longitudinal control force.

d. Procedures.

(1) Basic compliance is determined by the characteristics of $F_s/g$ (normally a plot). Any standard flight test procedure which yields an accurate evaluation of $F_s/g$ data in the specified range of speeds and acceleration should be considered for acceptance. Bounds of investigation and acceptability are set forth in the rule and in discussion material above, and broad pilot discretion is allowed in the selection of maneuvers.

(2) Investigation Range. Out-of-trim testing should be done at the most adverse loading for both high and low control forces. Testing should be accomplished both at the "Q" and Mach limits.

(3) The ability to actuate the primary controls (including trim), when loaded, should be considered prior to the tests.

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